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RESEARCH SUPPORT FOR PLASMA DIAGNOSTICS
ON ELMO BUMPY TORUS:
INVESTIGATION OF DIAMAGNETIC
DIAGNOSTICS FOR THE ELECTRON RINGS

by

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February 1981

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ABSTRACT

Diamagnetic diagnostics for the EBT electron rings are fundamental to the experiment. The diamagnetic flux pickup loops on each cavity output signals proportional to ring perpendicular energy. A data analysis technique is described, which in its simplest form is subtracting $1/4$ the signal from each neighboring cavity pickup loop from the central one's, which provides a signal proportional to the energy in a single ring. The calibration factor relating absolute perpendicular energy to diamagnetic signal depends weakly on the geometrical model for the ring. Calculations with a bumpy cylinder MHD equilibrium code give calibration factors in reasonable agreement (20%) to the values obtained using a simple, concentric cylindrical current sheet model. The cylindrical current sheet model is used to show that diamagnetic field components measured external to the plasma require high precision or correlation with other diagnostics in order to fix model parameters. A computer simulation shows an assumption of constant ring thickness and energy density with increasing length (and energy) is compatible to diamagnetic field observations on NBT.

FORWARD

This report covers the work performed during the period May 15, 1980, to January 31, 1981, under Basic Agreement No. 7676, Project Authorization No. X01, a subcontract from Union Carbide Corporation to the University of Missouri. This is the final report for this Project Authorization. The work was performed by the Principal Investigator, Dr. Kenneth H. Carpenter, with assistance from Mr. Frank Zykan during Summer 1980. Dr. Carpenter is Associate Professor in the Department of Electrical Engineering of the University of Missouri - Rolla, and Mr. Zykan was a Graduate Research Assistant in that department.

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Research Support for Plasma Diagnostics on Elmo Bumpy Torus -
Investigation of diamagnetic diagnostics for the electron rings

I. INTRODUCTION

Determination of the parameters of the hot electron rings in EBT is one of the basic goals of the experiment¹, having a significant roll to play in plasma power balance² and stability³ considerations. Diamagnetic flux pickup loops have been used since the beginning of the experiment as a diagnostic for the ring stored energy⁴. A single attempt was made to obtain data needed to establish ring geometry by measurement of the diamagnetic field axial components near the outside of the plasma⁵, but this measurement was not sufficiently useful to be made a part of the standard diagnostics. In a similar way, diamagnetic measurements have been made on the NBT experiment⁶ and the STM experiment.⁷ The fundamental importance of these diamagnetic measurements prompted studies into the calibration of existing diagnostics and feasibility of additional diamagnetic diagnostics. In this report the results of studies into three aspects of diamagnetic diagnostics will be presented -- elimination of intercavity cross talk effects in perpendicular energy signals via data analysis, assessment of possible observation of ring geometry using diamagnetic measurements, and calibration of perpendicular energy diagnostics using current sheet and MHD equilibrium models.

The use of diamagnetic flux pickup loops encircling each EBT cavity to indicate electron ring perpendicular energy ($W_{\perp}$) in the corresponding cavity is complicated by the fact that each $W_{\perp}$ signal contains varying contributions due to energy in neighboring cavities. To facilitate use of these $W_{\perp}$ signals in determining ring power distribution among the cavities a method was developed to resolve individual cavity $W_{\perp}$ values from the array of 24 cross coupled $W_{\perp}$ signals. For a wide range of ring geometries the cross coupling can be compensated to about 3% by the simple method of subtracting 1/4 of the raw $W_{\perp}$ signal from the two adjacent cavities from the raw $W_{\perp}$

signal of a given cavity and then multiplying the result by 8/7. A more accurate compensation algorithm has been incorporated in the computer code used to analyze data from plasma turn-downs. This is described in section II of this report.

Although ring perpendicular energy is an important plasma parameter, the confinement properties of that ring -- expressed by ring geometry and "beta" -- are equally important. Satisfactory diagnostics for ring geometry have not yet been achieved on EBT by means of diamagnetic measurements. Early attempts using small relay coils for diamagnetic field measurement lacked sufficient sensitivity to ring geometry to fix model parameters and simulation studies made then were not encouraging.^{5,8} Use of a Hall probe array on the STM experiment for this purpose⁷ prompted a fresh look at this possibility for EBT. Also a reported relationship between diamagnetic signals and (presumed) ring axial length for NBT⁹ prompted further comparisons of model rings and external diamagnetic field components. These studies are described in section III of this report.

Calibration of $W_{\perp}$ signals from the diamagnetic flux pickup loops is somewhat model dependent and of such importance as to merit study by more than one approach. In section IV we present results from preliminary calculations using a bumpy cylinder MHD equilibrium code for calibration of the $W_{\perp}$ signals.

Following the concluding comments and recommendations in section V, we present in the appendix the FORTRAN listings and sample inputs and outputs for the computer programs written for use in this work.

II. CORRECTION OF PERPENDICULAR ENERGY DIAMAGNETIC SIGNALS FOR CROSS TALK BETWEEN SECTORS

The $W_{\perp}$ signals used routinely as an indication of ring plasma energy in each EBT sector are subject to significant cross talk from adjacent sectors. A method to unfold the twenty-four $W_{\perp}$ signals to give twenty-four signals, each proportional to the perpendicular energy in a single electron ring, was developed and subsequently included in the data analysis program. A derivation of the algorithm and its implementation as a universal correction method is given in what follows.

Derivation of voltage-energy calibration in the presence of cross talk

Let the signal output by the integrator connected to the pickup loops on the i 'th sector be v_i , and let F_i be the diamagnetic flux linking one turn of the pickup loop. Then $v_i = F_i N/t$ where N is the number of turns and t is the integrator time constant (assumed the same for all i). Let the electron ring in each EBT sector be modeled by two current sheets. Let the inner current sheet have total current magnitude I_{i1} and the outer current sheet have total current magnitude I_{i2} . Let the mutual inductance coupling current sheet I_{i1} and pickup loop j be M_{ji1} , and let that linking I_{i2} and pickup loop j be M_{ji2} . The total flux linking one turn of pickup loop i is thus

$$F_i = \sum_{j=1}^{24} (M_{ij1} I_{j1} - M_{ij2} I_{j2}) + F_c \quad (1)$$

where the minus sign is used so that all M and I values can be positive with the outer and inner current sheets oppositely directed. F_c is the diamagnetic flux due to plasma not represented by the current sheets, i.e., the toroidal core plasma.

Given a specific geometry for a current sheet model, M_{ij1} and M_{ij2} can be calculated. We choose to use the concentric cylindrical current sheet model described in another report¹⁰

Based on it, a FORTRAN function DM has been written to calculate the M's. (A listing of the FORTRAN is given in the appendix.)

Lacking any knowledge to the contrary, we make the following key assumption: The geometry of all 24 electron rings is the same; that is, the M_{ij} values depend only on the difference between i and j (modulo 24) not on i and j separately. While this is not exactly true, computer studies show that the M_{ij} are only weakly geometry dependent¹⁰ so that the assumption does not introduce serious error.

The perpendicular energy in the model is given by

$$W_{\perp i} = 2\pi r(\Delta r) B_{\text{avg}} \frac{1}{2}(I_{i1} + I_{i2}) \quad (2)$$

where B_{avg} is a suitable average value for magnitude of total magnetic field (vacuum plus diamagnetic) over the region occupied by the ring. In (v-1) we have a set of 24 equations in 49 unknowns, the I_{i1} 's, I_{i2} 's, and F_c . To reduce the unknowns to 24 to allow for solution for the $W_{\perp}$'s via Eq.(2) we do the following. First $F_c \ll F_i$ is assumed and F_c is set to zero. Second the theoretical formula for drift current¹⁰ is used to fix the difference of I_{i1} and I_{i2} :

$$I_{i2} - I_{i1} = \frac{\Delta B}{2B} (I_{i2} + I_{i1}) \quad (3)$$

where ΔB is the difference between the magnetic field at the inner current sheet and that at the outer, and B is the mean value. This provides the additional 24 relations needed to solve eq(V-1) for the I_{j1} and I_{j2} values. (The term $DF = (1 + \Delta B/2B)$ is used in the computer codes to represent this "drift factor".) If we let $I_i = (I_{i1} + I_{i2})$ then $I_{i1} = I_i(1 - \Delta B/2B)$ and $I_{i2} = I_i(1 + \Delta B/2B)$ so that Eq.(1) becomes

$$\begin{aligned} F_i &= \sum_{j=1}^{24} [M_{ij1}(1 - \Delta B/2B) - M_{ij2}(1 + \Delta B/2B)] I_j \\ &= \sum_{j=1}^{24} C_{ij} I_j \end{aligned} \quad (4)$$

Now from the assumed identity of the geometrical factors for all sectors one has the property that C_{ij} is a symmetric circulant matrix:

$$C_{ij} = C_{ji} \quad (5)$$

$$C_{i+n, j+n} = C_{ij}, \text{ addition mod } 24.$$

Thus there are only 13 independent matrix elements for C_{ij} . Such a matrix can be inverted by Fourier techniques to give an inverse matrix D_{ij} having the same properties. Thus we have

$$I_i = \sum_j D_{ij} F_j \quad (6)$$

and through Eq.(2) the separated ring perpendicular energies.

FORTTRAN subroutines have been written to evaluate the C_{ij} and D_{ij} and to calculate (normalized) I_i 's given a set of F_j 's. These are listed in the appendix.

Correction matrix for diamagnetic flux signals

This same technique can be used to correct the v_i values to those that would be obtained if only flux from the i 'th ring contributed. Let such corrected values be labeled w_i . Then

$$\begin{aligned} w_i &= C_{ii} I_i N/t = C_{ii} \sum_j D_{ij} v_j \\ &= (d^{-1})_{11} \sum_{j=1}^{24} d_{ij} v_j \end{aligned} \quad (7)$$

where $d_{ii} = 1$. There are only 12 independent elements to the correction matrix C_{ij} which can be represented in terms of the normalized matrix d_{ij} having ones for all diagonal elements. The normalizing factor is the diagonal element of the inverse of the d_{ij} matrix. Let the twelve independent elements of d_{ij} be labeled as $f_i = d_{1, i+1}$, $i = 1, 2, \dots, 12$ and let $f_0 = (d^{-1})_{11}$. Then the correction algorithm to yield the signals due to the rings in a single sector only is

$$w_i = f_0(v_i + (v_{i+1} + v_{i-1})f_2 + (v_{i+2} + v_{i-2})f_3 \quad (8)$$

$$+ \dots + (v_{i+11} + v_{i-11})f_{12} + (v_{i+12})f_{13})$$

where addition of indices is modulo 24.

Results of a few representative runs are given in Table 1. One sees that for the model parameters tested one can use a universal "average" set f_i to correct for cross talk between sectors and still achieve an accuracy of at least 2% of the largest of the uncorrected readings. Since the precision of the v_i values is not better than 2%, this fixed, average f_i set was programmed into the EBT OFF data reduction routine used on the PDP-10. Thus EBT OFF now provides a cross talk correction option for analysis of plasma turn down data. A listing of the FORTRAN for this revised EBT OFF is given in the appendix.

Hand calculation algorithm

Note that nearly all the correction for cross talk comes from the two adjacent sectors. In fact, since the next nearest pair of sectors has the opposite sign ($f_3 > 0$; $f_i < 0$, $i > 3$) from the remaining ones, only about another 1% of error will be introduced if only the nearest neighbor sector corrections are made. For hand calculations to 3% accuracy, simply subtract one-fourth of each neighboring sector w_i voltage signal from the one whose corrected value is desired; then multiply this result by 1.15 to obtain the value that would have resulted if only that sector's ring had produced flux to link the pickup loop.

ring thickness	2.0	2.0	4.0	2.0	mean values	maximum deviations
ring mean radius	13.32	13.32	13.32	12.22		
drift factor	1.065	1.065	1.129	1.058		
ring length	5.0	10.0	10.0	10.0		
f_0	1.1424	1.1461	1.1448	1.1538	1.1468	0.007
f_2	-0.2475	-0.2505	-0.2494	-0.2565	-0.2510	0.0055
f_3	0.0176	0.0188	0.0184	0.0213	0.0190	0.0023
f_4	-0.0066	-0.0068	-0.0067	-0.0071	-0.0068	0.0003
f_5	-0.0013	-0.0012	-0.0012	-0.0011	-0.0012	0.0001
f_6	-0.0010	-0.0010	-0.0010	-0.0010	-0.0010	0
f_7	-0.0006	-0.0006	-0.0006	-0.0006	-0.0006	0
f_8	-0.0004	-0.0004	-0.0004	-0.0004	-0.0004	0
f_9	-0.0003	-0.0003	-0.0003	-0.0003	-0.0003	0
f_{10}	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	0
f_{11}	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	0
f_{12}	-0.0005	-0.0005	-0.0005	-0.0005	-0.0005	0
f_{13}	-0.0006	-0.0006	-0.0006	-0.0006	-0.0006	0

Table 1. Data from typical model ring calculations for perpendicular energy signal correction coefficients.

III. EXAMINATION OF RELATIONSHIP OF EBT ELECTRON RING GEOMETRY TO DIAMAGNETIC FIELD COMPONENTS WHICH CAN BE OBSERVED FROM OUTSIDE THE PLASMA

The fact that diamagnetic flux loop signals, which are used as a ring energy diagnostic, are insensitive to geometry is an indication that determination of ring geometry from diamagnetic field measurements will be difficult. A single attempt was made during the EBT-I period to obtain data to establish ring geometry by measurement of the diamagnetic field axial component at several points near the outside of the plasma⁵. This measurement was not sufficiently useful to be made part of the standard diagnostics.

Diamagnetic measurements have also been made recently on the NBT experiment⁶ and the STM experiment⁷. In order to understand the NBT results for the radial component of the magnetic field near the midplane versus ring energy⁹ and to assess the possibility of successfully applying the techniques used on STM to EBT, a re-examination of the relationship of parameters for a current sheet model of the rings to the diamagnetic field components was carried out. The details follow.

Previous ring field simulations and revised simulation code

In late 1976 a set of measurements of diamagnetic field axial components near the outside of the plasma was made using small relay coils as pickups. The resulting data was noisy and not able to give a definitive fit to the ring model parameters. This prompted a simulation study of the fields due to model rings to search for possible locations where field component measurements could discriminate between different ring geometries. (This study has been reported elsewhere^{5,8}.) The computer program used for this study output "arrow plots" which showed diamagnetic field versus position for given values of ring model parameters. The results were pessimistic for determination of ring model parameters by field component measurement at accessible locations. The lack of sensitivity of field components to model parameters is due to the fact

that field values a distance R from the center of a cylindrical current sheet having length L and radius A varies with A and L as $(A/R)^2 + (L/R)^2$ compared to one. Thus the requirement that measurements of field components be made outside the region containing the plasma (in order to prevent the probes' modifying the ring geometry itself) was responsible for the lack of success of the observations using the relay coils.

Reported use of Hall probes to obtain high precision magnetic field readings on the STM and NBT experiments prompted a restudy of feasibility of use of an array of diamagnetic field component measurements to determine ring geometry on EBT. The original "arrow plot" computer code was employed again, but this time including the theoretical $\Delta B/B$ drift current effect¹⁰ to reduce the number of free model parameters. A revised field simulation code (FLDEQ) was written to output the field components at fixed positions as functions of ring model parameters. (This code is listed in the appendix.) FLDEQ was used to simulate the NBT experimental data as well as to look again at the possibility of ring geometry determination for EBT using high precision field measurements.

Simulation of NBT radial diamagnetic field measurements

The NBT experiment used a Hall effect device, rather than a relay coil, to measure the plasma diamagnetic field. The Hall probe was oriented to give no output due to the vacuum field, hence its signal was the diamagnetic component normal to the vacuum field. This arrangement was simulated using the FLDEQ code by looking at the radial component of the magnetic field due to a concentric cylindrical current sheet model when the field point was 1 cm from the midplane and 5 cm from the outer current sheet.

The simulated signal for the magnetic field reproduces qualitatively the variation of the signals reported for NBT from a Hall effect detector as the ring energy is increased⁹. The qualitative result is compatible with an increase in ring axial extent (length) with increase in energy while maintaining a constant energy density. The simulated B_r signal is plotted versus axial extent assumed for the ring, in NBT geometry, in Fig. 1. The location of maximum B_r at

Fig. 1. Simulated radial diamagnetic field component versus length of model ring for a detector 1 cm away from midplane and 5 cm away from edge of ring. (NBT conditions) (Adjacent cavity effects included)

about 16cm for total length does not vary significantly with changes in assumed values for drift current effects and ring thickness.

Next the possibility of a similar variation of radial field with ring energy was explored for EBT conditions. Plots for B_r versus ring axial extent are given in Fig. 2 for EBT-I geometry for several possible detector locations at the outside of the EBT cavity. The maximum in signal occurs for larger ring lengths than in the NBT case primarily because the detector locations are farther from the model rings. Although it would be interesting to look for this fall off of field with increasing energy for EBT, it is not likely to be observed unless the rings are longer and nearer the outside of the machine than anticipated.

Finally we note that this result of decrease in magnetic field with increase in current sheet length is exactly what one would anticipate on a purely intuitive basis. For a constant energy density in the ring one has current sheets in the model with constant surface current densities. Zero length for the current sheet gives zero field. As the energy and length increase, the field at a fixed outside location increases at first, but as the length increases sufficiently the "ends" of the ideal solenoid become more distant, ultimately leading to continuously decreasing fields.

EBT ring geometry from external field measurements

The previous studies using "arrow plots" gave little hope for determination of ring parameters by external field measurements. In order to see what one might be able to do with more precise values for field components using Hall probes a study was carried out, using the FLDEQ simulation program. This study attempted to find how parameters of the current sheet model for EBT rings could be related by measuring diamagnetic field components at the outside edge of the cavity. If one assumes only relative calibration between detectors is available and not absolute field values then one can determine if the data is compatible with the model but cannot fix the model parameters. The ratios between detector signals are predicted to be nearly constant for a wide variation of choices for ring length and thickness, provided the radial location of the ring is set near the heating resonance and the drift current effect is near

Fig. 2. Simulated radial diamagnetic field versus length of model ring. Solid line for detector at coordinates (1,30), dashed line for detector at coordinates (10,30) with respect to cavity center. (Ring model thickness 2 cm assumed)(EBT-I geometry--adjacent cavity effects included)

the theoretical value. If an absolute calibration could be obtained for field component measurements as well as for the flux loop signals used to measure perpendicular energy then a determination of length, given thickness, could perhaps be made since the perpendicular energy measurement is less sensitive to length and thickness of the ring than some field component measurements. An attempt was made to make this connection between field and flux signals with the data taken in 1976, but some discrepancy was present in the relative calibration which prevented reaching any conclusions.

Simulated data was obtained for field components at several detector locations versus model ring length with other model parameters fixed. The field values were ratioed to the values obtained at the location nearest the midplane in order to eliminate an assumption of absolute calibration for experimental data. The resulting curves are plotted for one choice of ring thickness and radius in Fig. 3. Note that the slopes of the curves are small. Thus in the presence of experimental uncertainty accurate determination of length is difficult even with the model parameters of thickness, radius, and drift current effect known.

Since the other model parameters are not known a priori one can consider cases with both length and thickness unknown. Then for each field component a curve of length versus thickness can be made. An example is given in Fig. 4 using simulated B_r readings for a particular length and thickness. In this case the curves are nearly parallel so that the point of common intersection could not be found accurately in the presence of experimental uncertainties, although model length could be determined more accurately than thickness.

There is a need for field measurements at a combination of precision, absolute calibration and locations that would fix the parameters of the ring model -- not only to evaluate these parameters but also to determine the validity and usefulness of the model in further plasma calculations (from the goodness of the fit of the model to the data). The STM results indicate a more complicated ring model will be needed for good fits⁷. A possible approach is to use a MHD equilibrium model such as is described in the next section of this report.

Fig. 3. Simulated axial diamagnetic field components at outside of plasma (23.5cm from cavity center) relative to component at coordinates (1.6,23.5) near the midplane, versus length of model ring. (Ring thickness 2cm, mean radius 13.3cm assumed-- EBT-I geometry, adjacent cavity effects included)

Fig. 4. Length - thickness curves for simulated experimental Bz data for detectors at:

(4.2, 23.5) - ○
 (6.8, 23.5) - +
 (9.5, 23.5) - □
 (12.1, 23.5) - ×

Values ratioed to
 signal from detector at (1.6, 23.5)

IV. "BUMPY CYLINDER" MHD EQUILIBRIUM CODE MODEL FOR CALIBRATION OF ELECTRON RING ENERGY DIAGNOSTIC - COMPARISON TO CURRENT SHEET MODEL

The concentric cylindrical current sheet model that has been used to provide a calibration for the diamagnetic flux loops' perpendicular energy signal has been studied extensively.¹⁰ Although the calibration results obtained are quite insensitive to the model parameters (a fact attributed in part to the near Helmholtz coil arrangement of the pickup loops), which should imply similar calibration results would be obtained with other models, two questions still remain as to the validity of the result. The first question is on the adequacy of the handling of the drift current effect for the current sheets. The second is what is the proper choice of average magnetic flux density to use to multiply total magnetic moment to obtain perpendicular energy. Both of these questions are answered automatically if a MHD equilibrium model is used in place of current sheets.* In this section we will describe the modifications made to an existing MHD code, the normalization factors associated with the code output, and the problems and limitations of the code. The results of the MHD equilibrium code being applied to typical ring situations will be discussed and compared to the analogous current sheet results.

The bumpy cylinder MHD equilibrium code

We were provided a copy of the FORTRAN of the bumpy cylinder MHD code written by Hedrick¹¹ to serve as the basis for this work. The code uses a model of pressure as a separable function of flux, ψ , and field magnitude B with

*Remaining questions as to valid range of model parameters must be answered through the use of other diagnostic methods. Testing of these models has been done by assuming reasonable dimensions for electron rings centered near the rings' heating resonance.

$$g(\psi) = \begin{cases} (\psi - \psi_1)^2(\psi + \psi_1 - 2\psi_2)^2/(\psi_2 - \psi_1)^4, & \psi_1 \leq \psi \leq \psi_2 \\ 1, & \psi_2 \leq \psi \leq \psi_3 \\ (\psi - \psi_4)^2(\psi + \psi_4 - 2\psi_3)^2/(\psi_3 - \psi_4)^4, & \psi_3 \leq \psi \leq \psi_4 \\ 0, & \text{otherwise} \end{cases} \quad (9)$$

as the flux function and

$$\begin{aligned} p_{\perp} &= \frac{1}{2}S(B_c^2 - B^2)g(\psi) \\ p_{\parallel} &= \frac{1}{2}S(B_c - B)^2g(\psi) \end{aligned} \quad (10)$$

as the pressure functions. S is a positive constant less than one and B_c is a cutoff field value - pressure is zero for $B > B_c$. The code chooses the $\psi_1, \psi_2, \psi_3, \psi_4$ values at proper flux coordinates to give fixed (input) values for the radial position of the pressure profile in the midplane. The resultant equilibrium ring is thus a function of six input parameters to the code: four radial values r_i corresponding to the flux values ψ_i ; the cutoff field B_c ; and the constant S . The code calculates the equilibrium by iteration on the nonlinear MHD equation

$$\Delta^* \psi_p + \nabla(\ln \sigma) \cdot \nabla \psi_p = -\frac{r^2}{\sigma} \frac{\partial p_{\parallel}}{\partial \psi} - \nabla(\ln \sigma) \cdot \nabla \psi_c \quad (11)$$

where $\sigma = 1 + (p_{\perp} - p_{\parallel})/B^2$ and $\psi = \psi_p + \psi_c$ with ψ_c the vacuum flux. The right hand side and $\nabla(\ln \sigma)$ values are calculated using previous solutions for ψ , then Eq. (11) is solved by an S.O.R. finite difference algorithm and the process repeated. The code fixes the boundary conditions for Eq.(11) by using a multipole expansion of the field due to the plasma.¹¹

There are several auxiliary input parameters required by the code: number of sectors to represent an infinite bumpy cylinder, number of terms in multipole expansion, S.O.R. acceleration parameter, and outer loop solution mixing parameter. In addition the number of iterations to be performed on both inner and outer loops must be specified. Only a few of the many possible combinations of these

auxiliary parameters have been used, the choices being guided by trial runs and the experience of other users of the code.¹²

Several modifications were required to the FORTRAN of the MHD equilibrium code (titled EQUIL) in order to obtain the necessary output for calibration of the perpendicular energy diamagnetic signals. Most of the added code was placed in subroutine BATS to provide, on the final iteration, a numerical integration of pressure over space to give energy, and to provide an output of perpendicular pressure versus position in a format which gives a pressure map on the line printer. An output of total flux linking a specified circle of constant radial coordinate was also included. A number of smaller changes were made to input/output to make the code compatible with the UM computer network FORTRAN system. Certain sections of the code whose results were not needed for the present purpose were bypassed to reduce time required for execution, and some changes were made in the control of the iterations and the extent of the output. Since the code is over 2000 lines long a complete listing is not included with this report, but listings of the main program, which describes the modifications in comments, and of subroutine BATS, which contains the major additions, are given in the appendix.

Normalization of variables in EQUIL code - specification of input values - interpretation of output values

All length variables in EQUIL are assumed to be in centimeters. All plasma variables are normalized to the magnitude of magnetic flux density at the center of the midplane, B_0 . Further, factors of μ_0 that would be required for SI units are omitted. The FORMAT statements in the code specify how the input variables must be entered, but the input variables and their interpretations are repeated in the output. Since the interpretation of variables given in the computer output is not always clear, and since an understanding of these is necessary for use of the code and interpretation of the results, the input parameters and output values are briefly described in the appendix where a sample output is given.

The normalization of the output values produced by EQUIL was carefully traced through the FORTRAN listing to be sure all the numerical constants were taken into account. Since the code only treats one-half a mirror section due to symmetry the total ring energy is a factor of two times the value obtained by numerical integration in the code. As a result the values given in Table 2 were obtained. In particular we note that the ring "beta" relative to the field at the center of the midplane, $\beta_{\perp} = 2p_{\perp}\mu_0/B_0^2$, is just twice the computed value of PERP; the perpendicular energy of the ring in Joules is ten times the computed value WPER multiplied by B_0^2 in (Tesla)²; the flux linking a circle of radius corresponding to the index L in SI(L) in Webers equals the SI(L) value times 6.28×10^{-4} times B_0 in Tesla. Note that local ring beta is typically a factor of $2 \frac{1}{2}$ times greater than $\beta_{\perp}$ defined with respect to B_0 .

General observations on EQUIL output

Sample output from representative runs of the MHD equilibrium program EQUIL are given in the appendix. Some general comments on qualitative results and limitations on their reliability will be presented here. First we note that the pressure model built into the code implies that, for a fixed radial profile for the ring, the higher the beta the longer the ring in the toroidal direction. Whether or not this implication of the model is also true for the actual ring is significant for ring diagnostics, since a ring long enough to be "high" beta is too long to be adequately represented by a circular cylinder model. In EQUIL runs we have made to date we have achieved less than 20% beta for rings when the length was forced to be about 10 cm.

We note that for the runs of EQUIL made to date that had beta values high enough to achieve a local minimum in B versus r, the $W_{\perp}$ values that resulted should produce diamagnetic flux signal voltages (>500 mV) that are greater than those observed for EBT-I turn-downs (<300 mV). However, no systematic study has been made on this topic.

There remain matters of numerical precision to be resolved with the EQUIL code itself. The code is written in single precision

beta %	2	8	18	23
radial shape	triangle	trapezoid	triangle	trapezoid
r_1	11	11	11	11
r_2	13	12	13	12
r_3	13	14	13	14
r_4	15	15	15	15
$\left(\frac{W_{\perp}}{\text{Volt}}\right)$	32	32	30	28

Table 2. Diamagnetic flux pickup loop calibration factors from MHD equilibrium model. ($B_0 = 5000(\text{G})$).

FORTTRAN and executed on a 32 bit word computer. Since the solution is done by iteration, roundoff errors are less of a problem, but a test case should be run in double precision. The size of the finite difference mesh was checked at two values, and though the results changed, the finer mesh moved the calibration factor for the diamagnetic flux signal toward a smaller energy per volt. The number of iterations on a given run was increased successively until only small changes in results occurred for additional iterations in both outer and inner loops. We note that increasing the number of iterations also reduces the energy per volt factor. We also observe that the values for pressure converged much more rapidly than the values for diamagnetic flux. This is due to pressure being determined by the total flux on which the diamagnetic value is only a perturbation. The number of multipole terms in the boundary condition expansion was fixed at 10 and the number of sectors to approximate an infinite bumpy cylinder was fixed at 7. Obviously a great deal more effort could be spent assessing the effects of these numerical matters, but the qualitative conclusions are not expected to change.

Current sheet model for bumpy cylinder

In order to make a direct comparison of diamagnetic flux signal calibration in a MHD and a current sheet model, a program was written, similar to the one used to calculate the mutual inductances for the bumpy torus, to provide the calibration factor for a bumpy cylinder with an arbitrary number of sectors. This code (BUMCAL) is listed in the appendix. The code outputs normalized flux linkage for single current sheets. The drift factor effect for the concentric current sheet model is then calculated by hand. The input values given to the program are the number of sectors, the current sheet radius, the current sheet width, and the separation between adjacent sectors (all in centimeters). The output is a value APT which is the normalized flux linkage for a pickup loop in a position similar to the diamagnetic flux loops on EBT (radius 28cm, location 9.5cm from midplane). The normalization in the code is such that to obtain the dimensional flux linking one turn of the pickup loop one must multiply the value of APT by $\mu_0 RI/2$ where R is pickup coil radius and I is total current

for the sheet. Thus the formula to obtain the flux pickup loop calibration factor is

$$\frac{W_{\perp}}{\text{Volts}} = \frac{B_{\text{avg}}}{(\mu_0/4\pi)} \frac{r(\Delta r)t}{RN} \frac{1}{[(1 + (\Delta B/2B))AP_{\text{out}} - (1 - (\Delta B/2B))AP_{\text{in}}]} \quad (12)$$

where B_{avg} is the proper "average" value of total magnetic flux density over the model ring to convert dipole moment to energy. Δr is ring thickness, r is ring mean radius, N is number of turns on the pickup coil, t is integrator time constant, ΔB is change in magnetic field across the ring thickness and B the mean value.

One case was run for comparison to the MHD values. For it $R = 28$ cm, $r = 13$ cm, $\Delta r = 2$ cm, $L = 10$ cm and BUMCAL gave $AP_{\text{out}} = 1.0076$ and $AP_{\text{in}} = 0.7394$. The values assumed for $\Delta B/B$ and B_{avg} have a significant bearing on the result. To agree with the procedure used for the EBT current sheet model the value taken for $\Delta B/B$ corresponded to the vacuum field in the midplane (as read from the output for a low beta case from EQUIL). If B_{avg} is taken as the value near the center of a corresponding low beta run of EQUIL then $B_{\text{avg}} = 0.255$ (T) for a field of 5000 Gauss at the center of the midplane. Substituting these values in Eq. (12) gives a numerical value for the calibration factor of 26 (Joule/volt). Obviously there is room for considerable uncertainty in the B_{avg} value used as well as in $\Delta B/B$. No other cases have been checked, but experience with the bumpy torus current sheet model shows that little change is to be expected for different thickness Δr or length L as long as the other values remain the same.

Comparison of MHD equilibrium model and current sheet model flux loop energy calibration factors

Four cases have been run with EQUIL using input values that yield rings that can reasonable be compared with the cylindrical current sheet model. Each had a length of about 10cm and was approximately cylindrical in geometry (as can be seen in the EQUIL sample output in the appendix). The radial cross section, beta

values, and flux loop calibration factors are summarized in Table 3. We note that pickup loop calibration factors exceeded the current sheet model value of 26 (Joule/volt) by a range of 10 to 20%.

A 20% agreement between as crude a model as cylindrical current sheets compared to a MHD equilibrium is encouraging. The difference is no doubt due in part to the choice of B_{avg} and $\Delta B/B$ for the current sheet model. A concern for the accuracy of the MHD model results needs to be mentioned however. In each case listed in Table 3 the radial increment for the finite differences was 0.25cm. This put only 16 points across the ring. The case of 2% beta and triangular radial profile was also run with a 0.5cm radial increment. A result of 39 (Joule/volt) was obtained, which is 20% higher than the result for 0.25cm increments. A further reduction in increment size could reduce the calibration factor to a value more nearly in agreement with the current sheet model. Time did not allow such runs of EQUIL to be made during the period of this subcontract.

A word of caution must be given about using these bumpy cylinder flux pickup loop calibrations for the $W_{\perp}$ signals on EBT. First, although the loop placement was chosen to be as near to the EBT value as possible, there is still a difference between the toroidal and cylindrical geometries. Second, the EQUIL code runs and BUMCAL runs were made using a separation between adjacent mirror coils of 44.5 cm. The separation at 15° for a 150 cm major radius torus would be 39cm. The proper equivalent separation for a bumpy cylinder for comparison of calibration factors is not clear, but it is clear that adjacent sector cross talk is a bigger factor for the bumpy cylinder, all other effects being equal. However, the current sheet model for EBT gives values for $W_{\perp}$ signal calibration not far different from those found for the bumpy cylinder.¹⁰

Computer Output Numbers	→ multiply by	dimensional quality when $B_0 = 5000$ (Gauss)	→ multiply by	for dimensional quantity for any B_0
P-PERP	1.989×10^5 (Nt - m ⁻²)	perpendicular pressure		$(B_0/5000 \text{ (Gauss)})^2$
P-PERP	2	ring beta		1
SI(L)	6.283×10^{-4} (Weber)	magnetic flux linkage		$B_0/5000 \text{ (Gauss)}$
MODB	5000 (Gauss)	magnetic flux density		$B_0/5000 \text{ (Gauss)}$
WPER	2.50 (Joules)	ring perpendicular energy		$(B_0/5000 \text{ (Gauss)})^2$
WPAR	1.25 (Joules)	ring parallel energy		$(B_0/5000 \text{ (Gauss)})^2$
(WPER/SI(L))	$3.79 \left(\frac{\text{Joule}}{\text{Volt}}\right)$	flux pickup loop calibration factor		$B_0/5000 \text{ (Gauss)}$

Table 3. Numerical factors to convert output from EQUIL computer code to dimensional quantities.

V. CONCLUDING COMMENTS AND RECOMMENDATIONS

The work discussed above is by no means the last word on diamagnetic diagnostics for EBT electron rings. However, important advances have been made in understanding these diagnostics, which we will point out again along with giving our recommendations for additional work in these areas.

The cavity cross talk compensation algorithm for the perpendicular energy signals described in section II is simple and has proven successful in use. The implementation in the EBTOFF code is applicable to EBT-I/S only, however a similar program could easily be written for other machines. One must caution users that the "universal" set of correction numbers written into EBTOFF works best for rings with mean radii near 13cm. Accuracy will be reduced if the machine is run in a mode that would produce rings significantly larger or smaller. In any event, the test of accuracy is the corrected signal output for a cavity with zero input power (which should be near zero).

The examination given to the possibility of obtaining ring geometrical data from diamagnetic field component measurements leaves the projected outcome of such an experiment with a great deal of uncertainty. It is the feeling of the author that the best possible set of diamagnetic data should be obtained. If this is not definitive in itself, it can be correlated to non-diamagnetic diagnostics as they become available. Further work is needed on the use of alternate models for ring geometry, including parameterizations of 3-D MHD equilibria.

The 2-D bumpy cylinder MHD equilibrium calculations have confirmed the basic validity of the use of a current sheet model for calibration of the diamagnetic perpendicular energy diagnostic. There still remain a sizeable number of calculations and code modifications to be done to finally establish the best values and check out possible numerical problems in the code. As 3-D MHD equilibria are generated for geometrical modeling they can also be used to check the $W_{\perp}$ calibration. As yet optimization has not been attempted on the pickup coil sizes, locations and orientations.

While not a major task, this needs to be considered, especially for application on any new or modified plasma experiment, such as EBT-P.

VI. REFERENCES

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APPENDIX - FORTRAN Listings and Inputs and Outputs

Cross talk compensation programs

The routines written to achieve the unfolding of intercavity cross talk between $W_{\perp}$ signals have their FORTRAN listings given on the following pages. These listings are in the form of a compressed format file used with the UM computer network IBM-CMS software. Subroutines called, but not in the listing, were used in prior work at ORNL and are available on the FED PDP-10 computer.

All the main programs listed prompt for input interactively or else read as input a file produced by one of the other main programs. All output is via the NAMELIST method for easy data identification. Outputs used in determining the universal correction values programmed in EBT OFF are given in the pages following the FORTRAN listings.

:READ AIMI EXEC A1 TEMP 07/21/80 09:55:02

 &1 &2 LTAIMI EXEC A1

 &1 &2 CAIMI EXEC A1

 &1 &2 AIOC FORTRAN A1

 &1 &2 BMNORM FORTRAN A1

 &1 &2 DM FORTRAN A1

 &1 &2 EBTOFT FORTRAN A1

 &1 &2 MIJE1 FORTRAN A1

 &1 &2 SYMCIR FORTRAN A1

 &1 &2 TAIMI FORTRAN A1

 &1 &2 TDM FORTRAN A1

 &1 &2 TSTSYM FORTRAN A1

 &1 &2 ZEROIN FORTRAN A1

:READ LTAIMI EXEC A1 TEMP 07/21/80 09:40:43

LOAD TAIMI MIJE1 AIOC SYMCIR DM ZEROIN SLFL AS1 SASIMP SGAUS8 (NOMAP
GENMOD TAI

:READ CAIMI EXEC A1 TEMP 07/21/80 09:40:43

FORTGI TAIMI (NOPRINT NOTERM

FORTGI MIJE1 (NOPRINT NOTERM

FORTGI AIOC (NOPRINT NOTERM

FORTGI DM (NOPRINT NOTERM

FORTGI SYMCIR (NOPRINT NOTERM

FORTGI ZEROIN (NOPRINT NOTERM

:READ AIOC FORTRAN A1 TEMP 07/21/80 09:40:43

 SUBROUTINE AIOC(AIO,EF)

C K.H.CARPENTER 11JUL80.

C APPLIES INVERSE MUTUAL INDUCTANCE MATRIX BM TO INPUT WPER SIGNAL
C VALUES EF TO GIVE UNFOLDED WPER VALUES AIO (NORMALIZED).

C NORMALIZATION OF WPER FOR I'TH CAVITY IS:

C $WP(I) = (AIO(I) - AIO(K)) * BV(I) / CPHI / NTURN / (MU0 / TWOPI)$

C WHERE BV(I) IS "AVERAGE" MAGNETIC FLUX DENSITY OVER ANNULUS,

C CPHI IS VALUE FLUX LINKING PICKUP COIL IS MULTIPLIED BY TO

C OBTAIN EF(I), AND NTURN IS TOTAL NO. OF TURNS IN SERIES

C IN PICKUP COILS ON CAVITY I. AIO(K) IS RESIDUAL VALUE FOR

C CAVITY WITH NO ANNULUS.

C FOR DETAILS SEE KHC 9JUL80.

C

 COMMON/CMIJE1/BM(13),AM(13),V1

 DIMENSION AIO(24),EF(24)

C MULTIPLIES INPUT VECTOR EF BY MATRIX BM TO OBTAIN OUTPUT
C VECTOR AIO.

C BM IS A SYMMETRIC, CIRCULANT MATRIX OF DIMENSION 24.

 DO 100 I=1,24

 N=MOD(I-1,24)

 IF(N.EQ.0)N=24

 AIO(I)=BM(1)*EF(I)+BM(13)*EF(N)

 DO 50 J=2,12

 N1=MOD(I+J-1,24)

 IF(N1.EQ.0)N1=24

 N2=MOD(25+I-J,24)

 IF(N2.EQ.0)N2=24

 AIO(I)=AIO(I)+BM(J)*(EF(N1)+EF(N2))

50 CONTINUE

100 CONTINUE

 RETURN


```

END
:READ  BMNORM   FORTRAN  A1 TEMP   07/21/80 09:40:43
C      BMNORM    K.H.CARPENTER  16JUL80
C      PROGRAM TO OUTPUT NORMALIZED ARRAY OF BM WITH BM(1)=1
C      AND AN ARRAY NORMALIZED BY MULTIPLYING BY AM(1).
C      DIMENSION AIO(24),EF(24),BM(13),AM(13),BN(13),BMN(13)
C      NAMELIST/NORM/BN,BMN,AL,RT,DF,B0,GHZ,RR,XR,BZ
C      NAMELIST/TAIOUT/AL,RT,DF,B0,GHZ,EF,AIO,BM,AM,V1,RR,XR,BZ,IERR
5      READ(3,TAIOUT,END=100)
      DO 10 K=1,13
      BN(K)=BM(K)/BM(1)
      BMN(K)=BM(K)*AM(1)
10     CONTINUE
      WRITE (7,NORM)
      GO TO 5
100    STOP
      END

:READ  DM        FORTRAN  A1 TEMP   07/21/80 09:40:44
C      FUNCTION DM(DEG,RI,RO,CO,AL,DF,RE,ZO,AMR,IERR)
C      K.H.CARPENTER 8JUL80
C      RETURNS NORMALIZED MUTUAL INDUCTANCE VALUE BETWEEN
C      DIAMAGNETIC PICKUP LOOPS AND EBT ANNULUS IN CURRENT
C      SHEET MODEL.  ARGUMENTS ARE:
C      DEG = ANGLE IN DEGREES BETWEEN CAVITY WITH ANNULUS
C      AND CAVITY WITH PICKUP LOOPS
C      RI  = RADIUS OF INNER CURRENT SHEET
C      RO  = RADIUS OF OUTER CURRENT SHEET
C      CO  = OUTWARD DISTANCE FROM CENTER OF CURRENT SHEET
C      TO CENTER OF PICKUP LOOP
C      AL  = LENGTH OF CURRENT SHEETS
C      DF  = DRIFT FACTOR (1 + DB/B/2)
C      RB  = RADIUS OF PICKUP LOOPS
C      ZO  = HALF OF DISTANCE BETWEEN PICKUP LOOPS
C      AMR = DISTANCE FROM CENTER OF MACHINE TO CENTER
C      OF PICKUP LOOPS
C      RESULT IS INDEPENDENT OF UNITS USED FOR DISTANCE,BUT
C      UNITS MUST BE THE SAME FOR ALL ARGUMENTS.
C      THE ARGUMENTS ABOVE ARE UNCHANGED ON RETURN.
C      IERR= ERROR INDICATOR. IF IERR=0, NO ERROR.
C      ON RETURN DM CONTAINS THE VALUE OF THE NORMALIZED
C      MUTUAL INDUCTANCE BETWEEN THE PICKUP LOOPS AND THE CURRENT
C      SHEETS. THE NORMALIZATION IS:
C      M  =  DM*N*T*MU0/(2*PI)  WHERE
C      N  = TOTAL TURNS IN PICKUP LOOPS
C      T  = RO-RI
C      VOLTAGE SIGNAL FROM PICKUP LOOPS (2 IN SERIES WITH TOTAL
C      TURNS N) DUE TO THIS ANNULUS IS EQUAL TO M*TC*JM*AL WHERE
C      TC IS INTEGRATOR TIME CONSTANT AND
C      JM IS MAGNETIC DIPOLE MOMENT PER UNIT VOLUME
C      FOR ANNULUS ELECTRONS (MEAN SURFACE CURRENT).
C
DOUBLE PRECISION DPI
COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ
COMMON/CSLFL/FL,B,XB,ZB,ADEG,CX,SX,XBR,BSX,BCX
DATA DPI/3.141592653539793D0/

```

```

DATA NG/4/,NS/8/
IERR = 0
NG1=NG
C PICK UP ARGUMENTS AND PUT IN COMMONS:
ADEG = DEG
AL2 = AL/2.0
B = RB
C SET FOR OUTER CURRENT SHEET
R1=RO
C CALCULATE VALUES FOR ROTATIONAL TRANSFORM
ARAD=DEG*DPI/180.D0
CA=COS(ARAD)
SA=SIN(ARAD)
ZC=Z0*CA
TZC=2.*ZC
ZS=Z0*SA
TZS=2.*ZS
C SET XB,ZB FOR 1ST COIL
ZB=ZC+AMR*SA
XB=-ZS+AMR*CA-AMR+CO
C NO INTEGRATION REQUIRED IN SLFL FOR SYMMETRIC CASE
IF((ADEG.EQ.0.OR.ADEG.EQ.180.).AND.CO.EQ.0.)NG1=0
CALL SLFL(NG1,NS)
AM1=FL
C SET XB,ZB FOR 2ND COIL
ZB=ZB-TZC
XB=XB+TZS
CALL SLFL(NG1,NS)
AM1=AM1+FL
C SET FOR INNER CURRENT SHEET
R1=RI
CALL SLFL(NG1,NS)
AM2=FL
C SET FOR 1ST COIL AGAIN
ZB=ZB+TZC
XB=XB-TZS
CALL SLFL(NG1,NS)
AM2=AM2+FL
DM=(DF*AM1+(DF-2.)*AM2)*RB*RB/AL2/(RO-RI)
RETURN
END
:READ EBTOFT FORTRAN A1 TEMP 07/21/80 09:48:14
C EBTOFT K.H.CARPENTER 21JUL80
C PROGRAM TO OUTPUT NORMALIZED ARRAY OF AIO WITH
C WITH AION(K)=AIO(K)*AM(1).
DIMENSION AION(24),AIO(24),EF(24),BM(13),AM(13),BN(13),BMN(13)
NAMELIST/NORM/AION,AIO,AL,RT,DF,B0,GHZ,RR,XR,BZ
NAMELIST/TAIOUT/AL,RT,DF,B0,GHZ,EF,AIO,BM,AM,V1,RR,XR,BZ,IERR
5 READ(3,TAIOUT,END=100)
DO 10 K=1,24
AION(K)=AM(1)*AIO(K)
10 CONTINUE
WRITE (7,NORM)
GO TO 5
100 STOP

```

```

END
:READ MIJE1      FORTRAN A1 TEMP      07/21/80 09:40:44
SUBROUTINE MIJE1(AL,RT,DF,B0,GHZ,IERR)
C      K.H.CARPENTER 14JUL80
DOUBLE PRECISION A(13),B(13),V(13),W(5),DET
COMMON/CMIJE1/BM(13),AM(13),V1
COMMON/CWPER/RR,XR,BZ
DATA Z0/9.5/, AMR/150./, RB/30.0/
EXTERNAL ZERFUN
C*****
C      This routine accepts annulus parameters and calculates
C      normalized mutual inductance matrix AM and its inverse BM
C      as per KHC 9JUL80. Annulus offset from cavity center
C      and mean radius calculated from Colestock midplane field
C      model as in WPER1 code.
C      This subroutine written for EBT-I/S - could be
C      modified for EBT-P, etc., by change of major radius AMR,
C      pickup coil separation 2.*Z0, and midplane field model.
C
C      INPUT ARGUMENTS:
C
C              AL              =      total length of assumed annulus in
C                                      toroidal direction (in cm)
C
C              RT              =      radial thickness assumed for annulus
C                                      (in cm)
C
C              DF              =      drift current factor (=1 for none,
C                                      >1 for aiding annulus flux, <1 for
C                                      opposing annulus; =0 for routine to
C                                      calculate value)
C
C              B0              =      midplane central vacuum field (in Gauss)
C
C              GHZ              =      res. freq. of annulus electrons(in GHz)
C
C      ON OUTPUT:
C
C              IERR              =      0, if no error
C                                      -1, if argument in error on call.
C                                      >0, if error detected in num. method.
C
C              DF              =      unchanged if >0 on call; set to
C                                      calculated value if =0 on call
C
C              AM              =      normalized mutual inductance matrix
C                                      values - normalization is:
C                                               $M = AM * NTURN * RT * MU0 / TWOPI$ 
C
C              BM              =      inverse matrix to AM
C
C              Element I of AM(I) or BM(I) corresponds to M(1,I)
C                                      of symmetric, circulant matrix M of mutual ind.
C
C              V1              =      1st eigenvalue of AM.

```

```

C
C*****
C
C      TEST INPUT ARGUMENTS FOR RANGE:
C      IF(GHZ.LE.0..OR.B0.LE.0..OR.AL.LE.0..OR.RT.LE.0.)GO TO 100
C
C      FIND RING MEAN RADIUS AND CENTER FROM RESONANCE AT
C      GHZ AND COLESTOCK FIELD MODEL
C
C      BZ=357.3*GHZ/B0
C      XOUT=ZEROIN(-2.,30.,ZERFUN,0.1)
C      XIN =ZEROIN(-30.,-2.,ZERFUN,0.1)
C      XR=0.5*(XOUT+XIN)
C      RR=0.5*(XOUT-XIN)
C
C      IF DF<0, CALCULATE DF FROM COLESTOCK FIELD MODEL AND FORMULA
C      DF=1.+0.5*DELB/B
C
C      IF(DF.LE.0)DF=1.+0.5*(PAT(XOUT-0.5*RT)-PAT(XOUT+0.5*RT))/BZ
C
C      SET FIXED PARAMETERS FOR CALL TO DM
C      RI=RR-0.5*RT
C      RO=RI+RT
C      CO=-XR
C      INITIALIZE LOOP
C      IERR=0
C      DEG=-15.0
C      CALCULATE AM MATRIX ELEMENTS
C      DO 50 I=1,13
C          DEG=DEG+15.0
C          A(I)=DM(DEG,RI,RO,CO,AL,DF,RB,Z0,AMR,IER)
C          AM(I)=A(I)
C          IERR=IERR+IER
50      CONTINUE
C      INVERT AM TO GET BM
C      IFLG=1
C      CALL SYMCIR(A,V,B,W,DET,24,IFLG)
C      IF(IFLG.NE.3)IERR=IERR+200
C      V1=V(1)
C      DO 60 I=1,13
60      BM(I)=B(I)
C      RETURN
100     IERR=-1
C      RETURN
C      END
C      FUNCTION ZERFUN(X)
C      COMMON/CWPER/RR,XR,BZ
C      ZERFUN=BZ-PAT(X)
C      RETURN
C      END
C      FUNCTION PAT(X)
C      Colestock fit to midplane field restricted to zero angle.
C      (Agrees with measured values. For agreement with calculated
C      values, multiply values by 1.0176.)
C      T2=0.

```

```

R=X
IF(X.GE.0.)GO TO 10
T2=3.14159**2
R=-X
10 PT=T2*(1.-3.724E-2*T2)
C1=(PT+20.81)*1.046E-4
C2=C1-2.04158E-3
C3=(PT+12.43)*.5966
AL=C1+C2*SIN((R-13.8)/C3)
PAT=EXP(-AL*((X+2.90281)**2))
RETURN
END
:READ SYMCIR FORTRAN A1 TEMP 07/21/80 09:40:46
C SUBROUTINE SYMCIR(U,V,B,W,D,N,I)
C FINDS EIGENVALUES, DETERMINANT, AND INVERSE FOR A REAL,
C SYMMETRIC, CIRCULANT, N X N MATRIX A(I,J) HAVING
C A(I,J)=A(J,I) AND A(I,J)=A(I+L,J+L), (SUBSCRIPTS ADDED MOD N).
C
C AUTHOR: KENNETH H. CARPENTER
C DEPARTMENT OF ELECTRICAL ENGINEERING
C UNIVERSITY OF MISSOURI - ROLLA
C DATE: 17APRIL1980
C
C U,V,B DIMENSIONS ARE: M = N/2 + 1, N EVEN; OR
C M = (N+1)/2, N ODD.
C W DIMENSION IS: M - 1, N ODD; N/4 - 1, N EVEN.
C
C ARGUMENTS: ON INPUT -
C U IS A ONE DIMENSIONAL ARRAY CONTAINING THE INDEPENDENT ELEMENTS
C OF A(I,J): U(J) = A(1,J), J = 1,2,...M
C N IS THE DIMENSION OF A(I,J)
C I IS A STATUS FLAG (= 0 OR 1 IF THIS IS THE FIRST CALL FOR THE
C CURRENT VALUE OF N AND 2 OR 3 FOR SUBSEQUENT CALLS FOR THE
C SAME N WITH THE CONTENTS OF W UNCHANGED SINCE THE PREVIOUS
C CALL);
C FOR I=0 OR 2, B IS NOT CALCULATED AND U IS UNCHANGED, WHILE
C FOR I=1 OR 3, B IS CALCULATED AND U IS OVERWRITTEN.
C
C ON OUTPUT -
C V IS A ONE DIMENSIONAL ARRAY CONTAINING THE M INDEPENDENT
C EIGENVALUES OF A(I,J). (ALL EXCEPT V(1) (AND, FOR EVEN N,
C VM(M)) ARE DOUBLY DEGENERATE.)
C D HAS THE VALUE OF THE DETERMINANT OF A(I,J) ON RETURN.
C
C IF I=1 OR 3, THEN THE V(I) VALUES ARE TESTED, AND IF THE SMALLEST
C ABS(V(I)) IS GREATER THAN N/AMMAX, WHERE AMMAX IS THE LARGEST
C FLOATING POINT NUMBER REPRESENTABLE WITHOUT OVERFLOW,
C THEN B IS RETURNED AS A ONE DIMENSIONAL ARRAY CONTAINING
C THE INDEPENDENT ELEMENTS OF THE INVERSE OF A.
C
C ON RETURN THE VALUES OF I HAVE THE FOLLOWING INTERPRETATIONS:
C = -2 IF I = 2 OR 3 ON CALL AND ROUTINE DETECTS CHANGE IN N
C = -1 IF N < 1 ON CALL
C = 2 IF B NOT CALCULATED AND U UNCHANGED FROM CALL
C = 3 IF B CALCULATED AND U OVERWRITTEN.

```

```

C
C      W IS A ONE DIMENSIONAL WORK ARRAY USED BY THE ROUTINE TO STORE
C      COSINE VALUES; W SHOULD NOT BE CHANGED BETWEEN CALLS.
C
C      ENTRY POINTS DEFINED IN THIS ROUTINE: SYMCIR, CCCOS, CCCCOS
C
C      THE FOLLOWING IS A DOUBLE PRECISION VERSION. TO CONVERT TO
C      SINGLE PRECISION, REMOVE THE "CS" CHARACTERS FROM THE
C      LINES BEGINNING WITH "CS", AND ADD "CD" CHARACTERS
C      TO THE FIRST OF THE FOLLOWING LINES.
C
C      THIS VERSION USES THE SYMMETRY OF THE MATRIX TO REDUCE THE AMOUNT
C      OF COMPUTATION, BUT DOES NOT USE AN FFT APPROACH. THIS VERSION
C      WILL BE THE MOST EFFICIENT IF N IS PRIME OR CONTAINS A LARGE
C      PRIME FACTOR. IF N IS A PRODUCT OF SMALL PRIMES IT WILL BE MORE
C      EFFICIENT TO IGNORE THE SYMMETRIC NATURE OF THE MATRIX AND USE
C      THE FFT METHOD TO INVERT THE GENERAL CIRCULANT MATRIX.
C
C      SUBROUTINE SYMCIR(U,V,B,W,D,N,I)
CS     REAL U(1),V(1),B(1),W(1),D
      DOUBLE PRECISION U(1),V(1),B(1),W(1),D
CS     REAL
      DOUBLE PRECISION CCCOS,AN,A,T,PN,AMMAX,ONE,VM,VM2,SINT,SIN1
      COMMON/CCCCOS/NO,NO2,NO4,IFOUR,IODD,IUP,IUPP
C      THE FOLLOWING VALUES MUST BE SET TO THE LARGEST ALLOWABLE FLOATING
C      POINT VALUE FOR THE COMPUTER BEING USED:
CS     DATA AMMAX/1.E37/
      DATA AMMAX/1.D37/
CS     DATA T/2.0/,ONE/1.0/
      DATA T/2.0D0/,ONE/1.0D0/
C      TEST N AND I AND BRANCH:
      IF(N.GE.1)GO TO 10
      I=-1
      RETURN
10     IF(N-2)300,400,20
20     IF(I.GT.1)GO TO 100
C      INITIALIZE COSTNE ARRAY FOR THIS N:
      NO=N
      NO2=N/2
      NO4=N/4
      IFOUR=MOD(N,4)
      IODD=MOD(N,2)
CS     PN=T*T*T*ATAN(1.0)/FLOAT(N)
      PN=T*T*T*DATAN(1.0D0)/DBLE(FLOAT(N))
      L=N/4 - 1 + IFOUR/2
      IF(IODD.EQ.1)L=(N-1)/2
      IF(L.LT.1)GO TO 50
CS     W(1)=COS(PN)
      W(1)=DCOS(PN)
      IF(L.LT.2)GO TO 50
CS     SIN1=SIN(PN)
      SIN1=DSIN(PN)
      IF(L.EQ.2)GO TO 40
      SINT=SIN1
      DO 30 K=2,L

```

```

        W(K)=W(K-1)*W(1)-SINT*SIN1
        SINT=SINT*W(1)+SIN1*W(K-1)
30      CONTINUE
        GO TO 50
40      W(2)=W(1)*W(1)-SIN1*SIN1
50      IUP=N/2 + IODD
        IUPP=IUP + 1 - IODD
C      CHECK STORED N:
100     IF(N.NE.NO)GO TO 500
C      CALCULATE EIGENVALUES:
        ISIGI=1
        DO 150 L=1,IUPP
CS      V(L)=U(1)+U(IUPP)*FLOAT(ISIGI*(1-IODD))
        V(L)=U(1)+U(IUPP)*DBLE(FLOAT(ISIGI*(1-IODD)))
        DO 130 K=2,IUP
            V(L)=V(L)+T*U(K)*CCOS((L-1)*(K-1),W)
130     CONTINUE
150     CONTINUE
C      CALCULATE DETERMINANT:
        D=V(1)
        IF(IODD.EQ.0)D=D*V(IUPP)
        DO 160 K=2,IUP
160     D=D*V(K)*V(K)
C      CHECK IF INVERSE TO BE ATTEMPTED:
        IF((I.EQ.0).OR.(I.EQ.2))GO TO 180
C      DETERMINE IF INVERSE CAN BE CALCULATED:
CS      VM=ABS(V(1))
        VM=DABS(V(1))
        DO 170 K=2,IUPP
CS      VM2=ABS(V(K))
        VM2=DABS(V(K))
170     IF(VM2.LT.VM)VM=VM2
CS      IF(VM.GT.(FLOAT(N)/AMMAX))GO TO 200
        IF(VM.GT.(DBLE(FLOAT(N))/AMMAX))GO TO 200
180     I=2
        RETURN
C      CALCULATE INVERSE:
200     I=3
C      IN THIS VERSION WE OVERWRITE U WITH THE RECIPROCAL OF V VALUES
        DO 210 K=1,IUPP
CS      U(K)=1.0/V(K)/FLOAT(N)
        U(K)=1.0D0/V(K)/DBLE(FLOAT(N))
210     CONTINUE
        ISIGI=1
        DO 250 L=1,IUPP
CS      B(L)=U(1)+U(IUPP)*FLOAT((1-IODD)*ISIGI)
        B(L)=U(1)+U(IUPP)*DBLE(FLOAT((1-IODD)*ISIGI))
        ISIGI=-ISIGI
        DO 230 K=2,IUP
            B(L)=B(L)+T*U(K)*CCOS((K-1)*(L-1),W)
230     CONTINUE
250     CONTINUE
        RETURN
C      SPECIAL CASE N=1:
300     D=U(1)

```

```

      V(1)=U(1)
      IF((I.EQ.0).OR.(I.EQ.2).OR.(D.LT.(ONE/AMMAX)))GO TO 310
      I=3
      B(1)=ONE/D
      RETURN
310   I=2
      RETURN
C     SPECIAL CASE N=2:
400   V(1)=U(1)+U(2)
      V(2)=U(1)-U(2)
      D=V(1)*V(2)
CS    VM=ABS(V(1))
      VM=DABS(V(1))
CS    VM2=ABS(V(2))
      VM2=DABS(V(2))
      IF(VM.GT.VM2)VM=VM2
      IF((I.EQ.0).OR.(I.EQ.2).OR.(VM.LT.(T/AMMAX)))GO TO 310
      I=3
      U(1)=T/V(2)
      U(2)=T/V(2)
      B(1)=U(1)+U(2)
      B(2)=U(1)-U(2)
      RETURN
500   I=-2
      RETURN
      END

C
C     FUNCTION CCCOS(M,W) RETURNS COS(2*PI*M/N) USING THE
C           VALUES PASSED IN W.
CS    FUNCTION CCCOS(M,W)
      DOUBLE PRECISION FUNCTION CCCOS(M,W)
CS    REAL W(1)
      DOUBLE PRECISION W(1),ONE,SI,ZERO
      COMMON/CCCCOS/N,NO2,NO4,IFOUR,IODD,IUP,IUPP
CS    DATA ONE/1.0/,ZERO/0.0/
      DATA ONE/1.0D0/,ZERO/0.0D0/
      IP=MOD(M,N)
      IF(IP.EQ.0)GO TO 200
      SI=ONE
      IF(IP.GT.NO2)IP=N-IP
      IF((IODD.EQ.1).OR.(IP.LE.NO4))GO TO 100
      IF(IP.EQ.NO2)GO TO 400
      SI=-ONE
      IP=NO2-IP
100   IF((IP.EQ.NO4).AND.(IFOUR.EQ.0))GO TO 300
      CCCOS=W(IP)*SI
      RETURN
200   CCCOS=ONE
      RETURN
300   CCCOS=ZERO
      RETURN
400   CCCOS=-ONE
      RETURN
      END

```

:READ TAIMI FORTRAN A1 TEMP 07/21/80 09:40:46


```

C      PROGRAM TAIMI  K.H.CARPENTER 14JUL80
C      PROVIDES A TEST DRIVER FOR ROUTINES MIJE1 AND AI0C.
      DOUBLE PRECISION A(13),B(13),V(13),W(5),DET
      COMMON/CMIJE1/BM(13),AM(13),V1
      COMMON/CWPER/RR,XR,BZ
      DIMENSION AI0(24),EF(24)
      NAMELIST/TAIOUT/AL,RT,DF,B0,GHZ,EF,AI0,BM,AM,V1,RR,XR,BZ,IERR
10     WRITE(5,20)
20     FORMAT(' TAIMI: ENTER AL,RT,DF,B0,GHZ,IOUT: (-1/ TO STOP)')
      READ(5,*)AL,RT,DF,B0,GHZ,IOUT
      IF(AL.LT.0.)STOP
      WRITE(5,30)
30     FORMAT(' ENTER EF ARRAY')
      READ(5,*)EF
      CALL MIJE1(AL,RT,DF,B0,GHZ,IERR)
      IF(IERR.NE.0)GO TO 40
      CALL AI0C(AI0,EF)
40     WRITE(IOUT,TAIOUT)
      GO TO 10
      END

:READ  TDM      FORTRAN  A1 TEMP  07/21/80 09:40:46
C      PROGRAM TDM  TESTS FUNCTION DM
C      TO USE: INPUT DATA TO PROMPT, ENTER -1/ TO STOP.
      NAMELIST/TDMOUT/DM0,IERR,DEG,RI,RO,CO,AL,DF,RB,Z0,AMR
10     WRITE(5,20)
20     FORMAT('/' ENTER DEG,AL,DF,RI,RO,RB,Z0,AMR,IOUT: (-1/ TO STOP)')
      READ(5,*)DEG,AL,DF,RI,RO,RB,Z0,AMR
      IF(DEG.EQ.-1.0)STOP
      DM0=DM(DEG,RI,RO,CO,AL,DF,RB,Z0,AMR,IERR)
      WRITE(IOUT,TDMOUT)
      GO TO 10
      END

:READ  TSTSYM   FORTRAN  A1 TEMP  07/21/80 09:40:47
C      PROGRAM TSTSYM
C      THIS IS A TEST MAIN PROGRAM TO CALL SYMCIR
C      DOUBLE PRECISION VERSION ONLY GIVEN HERE.
      DOUBLE PRECISION U(10),V(10),B(10),W(10),D,CCCOS
10     WRITE(6,20)
20     FORMAT(' ENTER N,I,U(K),K=1,M - I2,G10.5')
      READ(5,30)N,I
30     FORMAT(I2)
      J=N/2+1
      READ(5,35)(U(K),K=1,J)
35     FORMAT(G10.5)
      CALL SYMCIR(U,V,B,W,D,N,I)
      WRITE(6,40)U,V,B,W,D,N,I
40     FORMAT(8(5D13.5/),D13.5,I5,I5)
      DO 60 K=1,N
      D=CCCOS(K,W)
      WRITE(6,50)D
50     FORMAT(D15.5)
60     CONTINUE
      IF(1.GT.0)GO TO 10
      STOP
      END

```

ETAOUT

```
AL= 10.0000000 ,RT= 3.00000000 ,DF= 1.09708023 ,B0=
5000.00000 ,GHZ= 9.00000000 ,EF= 114.600006 , 92.0000000 ,
48.0000000 , 104.000000 , 113.600006 , 116.199997 ,
87.3999939 , 40.8000031 , 82.8000031 , 99.6000061 ,
81.6000061 , 93.6000061 , 108.000000 , 110.000000 ,
103.199997 , 62.8000031 , 40.8000031 , 93.3999939 ,
115.199997 , 33.6000061 , 63.6000061 , 122.000000 ,
126.399994 , 111.600006 ,AI0= 6.43681145 , 5.27251625 ,
.997003913E-01, 6.50013256 , 5.90026093 , 6.65853691 ,
4.94625378 , .164234638E-01, 4.83514404 , 5.85643291 ,
3.49065208 , 4.79494190 , 5.84751987 , 5.82244015 ,
6.04162216 , 2.82667542 , .404716969 , 5.39013100 ,
8.28197670 , -.896388590 , 2.69840908 , 7.45606613 ,
6.93386841 , 5.35542011 ,BM= .994147062E-01, -.248593614E-01,
.185210351E-02, -.670516165E-03, -.121717356E-03, -.975675357E-04,
-.570394041E-04, -.391296198E-04, -.281329267E-04, -.232965103E-04,
-.115305647E-04, -.488360820E-04, .565953669E-04,AM= 11.5228319 ,
2.97878742 , .599358559 , .197660506 , .869194269E-01,
.456470028E-01, .270777345E-01, .176216699E-01, .124043711E-01,
.939476490E-02, .766484067E-02, .676430762E-02, .647735596E-02,V1=
19.5079041 ,RR= 13.3253174 ,XR= -1.85566235 ,BZ= .643140078
```

IERR=

0

END

ETAOUT

```
AL= 5.00000000 ,RT= 2.00000000 ,DF= 1.06949806 ,B0=
5000.00000 ,GHZ= 8.50000000 ,EF= 114.600006 , 92.0000000 ,
48.0000000 , 104.000000 , 113.600006 , 116.199997 ,
87.3999939 , 40.8000031 , 82.8000031 , 99.6000061 ,
81.6000061 , 93.6000061 , 108.000000 , 110.000000 ,
103.199997 , 62.8000031 , 40.8000031 , 93.3999939 ,
115.199997 , 33.6000061 , 63.6000061 , 122.000000 ,
126.399994 , 111.600006 ,AI0= 5.86416721 , 4.78445053 ,
.155811429 , 5.88731003 , 5.39787102 , 6.06513882 ,
4.49230576 , .676904917E-01, 4.38873482 , 5.32783508 ,
3.20556450 , 4.37227058 , 5.33065796 , 5.31733894 ,
5.49566936 , 2.58036804 , .405781746 , 4.91212559 ,
7.49050140 , -.747633278 , 2.46193790 , 6.77848625 ,
6.32378101 , 4.90179729 ,BM= .892719626E-01, -.217317082E-01,
.142146717E-02, -.565325841E-03, -.119711083E-03, -.881914893E-04,
-.524385105E-04, -.357543904E-04, -.258233194E-04, -.211221777E-04,
-.112800544E-04, -.428857893E-04, .492925756E-04,AM= 12.7411957 ,
3.21279240 , .652116299 , .216091335 , .952306390E-01,
.500676930E-01, .297175273E-01, .193418711E-01, .136220455E-01,
.103174075E-01, .842146948E-02, .743104517E-02, .712260231E-02,V1=
21.3786163 ,RR= 14.0956726 ,XR= -1.77191162 ,BZ= .607410014
```

IERR=

0

END

Output from runs of TAIMI as main program, using actual W_L data for input as "EP".

&NORM

AI0N= 74.1702881 , 60.7543182 , 1.14883041 , 74.8999329 ,
 67.9877014 , 76.7251892 , 56.9948425 , .189244807 ,
 55.7145386 , 67.4826813 , 40.2221832 , 55.2512970 ,
 67.3799744 , 67.0909882 , 69.6165924 , 32.5713043 ,
 4.66348553 , 62.1095734 , 95.4318237 , -10.3289347 ,
 31.0933075 , 85.9149933 , 79.8977966 , 61.7095947 , AI0=
 6.43681145 , 5.27251625 , .997003913E-01, 6.50013256 ,
 5.90026093 , 6.65853691 , 4.94625378 , .164234638E-01,
 4.83514404 , 5.85643291 , 3.49065208 , 4.79494190 ,
 5.84751987 , 5.82244015 , 6.04162216 , 2.82667542 ,
 .404716969 , 5.39013100 , 8.28197670 , -.896388590 ,
 2.69840908 , 7.45606613 , 6.93386841 , 5.35542011 , AL=
 10.0000000 , RT= 3.00000000 , DF= 1.09708023 , B0= 5000.00000
 GHZ= 9.00000000 , RR= 13.3253174 , XR= -1.85566235 , BZ=
 .643140078

&END

&NORM

AI0N= 74.7164917 , 60.9596100 , 1.98522377 , 75.0113678 ,
 68.7753296 , 77.2771149 , 57.2373352 , .862457752 ,
 55.9177246 , 67.8829803 , 40.8427124 , 55.7079468 ,
 67.9189453 , 67.7492523 , 70.0213928 , 32.8769684 ,
 5.17014408 , 62.5863495 , 95.4379425 , -9.52574158 ,
 31.3680267 , 86.3660126 , 80.5725250 , 62.4547577 , AI0=
 5.86416721 , 4.78445053 , .155811429 , 5.88731003 ,
 5.39787102 , 6.06513882 , 4.49230576 , .676904917E-01,
 4.38873482 , 5.32783508 , 3.20556450 , 4.37227058 ,
 5.33065796 , 5.31733894 , 5.49566936 , 2.58036804 ,
 .405781746 , 4.91212559 , 7.49050140 , -.747633278 ,
 2.46193790 , 6.77848625 , 6.32378101 , 4.90179729 , AL=
 5.00000000 , RT= 2.00000000 , DF= 1.06949806 , B0= 5000.00000
 GHZ= 8.50000000 , RR= 14.0956726 , XR= -1.77191162 , BZ=
 .607410014

&END

Output from run of EBTOFT using output from TAIMI on previous page as input.

The following four pages list outputs from a run of TAIMI as the main program made to test effect of different ring parameters on compensation for cross talk.

ETAIOUT

```
AL= 5.00000000 ,RT= 2.00000000 ,DF= 1.06486034 ,B0=
5000.00000 ,GHZ= 9.00000000 ,EF= 1.00000000 , 1.10000038 ,
1.00000000 , 1.00000000 , 1.00000000 , .899999976 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 ,AI0= .489672050E-01, .613326654E-01,
.490226261E-01, .514102019E-01, .537977777E-01, .414877385E-01,
.538532026E-01, .512305349E-01, .514714420E-01, .514199734E-01,
.514176227E-01, .514147505E-01, .514093116E-01, .514186285E-01,
.514077134E-01, .514102019E-01, .514126904E-01, .514017753E-01,
.514110886E-01, .514056571E-01, .514027812E-01, .514004305E-01,
.513489544E-01, .515898652E-01,BM= .990983248E-01, -.245274417E-01,
.173927657E-02, -.651784008E-03, -.125958351E-03, -.975625735E-04,
-.573625875E-04, -.393594819E-04, -.282255060E-04, -.233532046E-04,
-.119005717E-04, -.482466567E-04, .557601597E-04,AM= 11.5278931 ,
2.95211792 , .596292496 , .197034359 , .867057443E-01,
.455598831E-01, .270307399E-01, .175967328E-01, .123821869E-01,
.938211381E-02, .765378401E-02, .675084069E-02, .646394119E-02,V1=
19.4513702 ,RR= 13.3253174 ,XR= -1.85566235 ,BZ= .643140078
```

IERR= 0

END

ETAIOUT

```
AL= 10.0000000 ,RT= 1.00000000 ,DF= 1.03247261 ,B0=
5000.00000 ,GHZ= 9.00000000 ,EF= 1.00000000 , 1.10000038 ,
1.00000000 , 1.00000000 , 1.00000000 , .899999976 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 ,AI0= .488801561E-01, .613665842E-01,
.489381552E-01, .513734594E-01, .538087636E-01, .413803384E-01,
.538667664E-01, .511788167E-01, .514373221E-01, .513827354E-01,
.513809100E-01, .513780303E-01, .513724610E-01, .513819903E-01,
.513708778E-01, .513734594E-01, .513760410E-01, .513649844E-01,
.513744541E-01, .513688885E-01, .513660125E-01, .513641834E-01,
.513095930E-01, .515681058E-01,BM= .998100638E-01, -.250309035E-01,
.188937155E-02, -.677948818E-03, -.120861834E-03, -.979338074E-04,
-.570778648E-04, -.392881921E-04, -.280924869E-04, -.234509789E-04,
-.113690639E-04, -.492614199E-04, .570950069E-04,AM= 11.4863062 ,
2.97735882 , .598560870 , .197297215 , .867392421E-01,
.455484614E-01, .270160288E-01, .175858475E-01, .123718567E-01,
.937622041E-02, .764355063E-02, .675517693E-02, .646110252E-02,V1=
19.4652710 ,RR= 13.3253174 ,XR= -1.85566235 ,BZ= .643140078
```

IERR= 0

END

ETAIOUT

```
AL= 10.0000000 ,RT= 4.00000000 ,DF= 1.12904644 ,B0=
5000.00000 ,GHZ= 9.00000000 ,EF= 1.00000000 , 1.10000038 ,
1.00000000 , 1.00000000 , 1.00000000 , .899999976 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 ,
```

```

1.000000000 , 1.000000000 , 1.000000000 , 1.000000000 ,
1.000000000 , 1.000000000 , AI0= .487029627E-01, .610840283E-01,
.487596467E-01, .511643924E-01, .535691455E-01, .412446633E-01,
.536258295E-01, .509767123E-01, .512268990E-01, .511738248E-01,
.511717983E-01, .511689298E-01, .511634424E-01, .511728004E-01,
.511618592E-01, .511643924E-01, .511669219E-01, .511559807E-01,
.511653386E-01, .511598550E-01, .511569902E-01, .511549525E-01,
.511018895E-01, .513520725E-01, BM= .990743041E-01, -.247115232E-01,
.181984040E-02, -.664131949E-03, -.122437021E-03, -.972918497E-04,
-.569572730E-04, -.390834466E-04, -.280735549E-04, -.232446619E-04,
-.115874645E-04, -.485625496E-04, .562350033E-04, AM= 11.5544739 ,
2.97996807 , .600070715 , .197984815 , .870789886E-01,
.457363129E-01, .271314979E-01, .176585019E-01, .124286041E-01,
.941408798E-02, .768080354E-02, .677836314E-02, .649178773E-02, V1=
19.5448151 , RR= 13.3253174 , XR= -1.85566235 , BZ= .643140078

```

IERR= 0

&END

:READ TAI DATAO A1 EBT1 07/16/80 12:15:41

&TAIOUT

```

AL= 10.0000000 , RT= 2.00000000 , DF= 1.06486034 , BO=
5000.00000 , GHZ= 9.00000000 , EF= 1.00000000 , 1.10000038 ,
1.00000000 , 1.00000000 , 1.00000000 , .899999976 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , AI0= .488445349E-01, .613095909E-01,
.489022546E-01, .513313822E-01, .537605137E-01, .413531289E-01,
.538182296E-01, .511381589E-01, .513949655E-01, .513406843E-01,
.513383328E-01, .513359345E-01, .513304099E-01, .513398610E-01,
.513288192E-01, .513313822E-01, .513339490E-01, .513228439E-01,
.513323620E-01, .513268262E-01, .513239279E-01, .513220802E-01,
.512678027E-01, .515246019E-01, BM= .996612906E-01, -.249662362E-01,
.187515398E-02, -.675019575E-03, -.121180856E-03, -.978387106E-04,
-.570504781E-04, -.392017682E-04, -.281514222E-04, -.233308092E-04,
-.115145758E-04, -.489770027E-04, .568088872E-04, AM= 11.5000076 ,
2.97789383 , .598870754 , .197425544 , .868030787E-01,
.455883741E-01, .270383172E-01, .175970830E-01, .123852938E-01,
.937997550E-02, .765311718E-02, .674944371E-02, .647038594E-02, V1=
19.4812469 , RR= 13.3253174 , XR= -1.85566235 , BZ= .643140078

```

IERR= 0

&END

&TAIOUT

```

AL= 10.0000000 , RT= 2.00000000 , DF= 1.00000000 , BO=
5000.00000 , GHZ= 9.00000000 , EF= 1.00000000 , 1.10000038 ,
1.00000000 , 1.00000000 , 1.00000000 , .899999976 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , AI0= .702444315E-01, .877200961E-01,
.703197718E-01, .736503601E-01, .769810081E-01, .595809072E-01,
.770562887E-01, .734175444E-01, .737339258E-01, .736650825E-01,
.736609101E-01, .736568570E-01, .736492276E-01, .736621022E-01,
.736469030E-01, .736503601E-01, .736537576E-01, .736385584E-01,

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.736514330E-01, .736439228E-01, .736397505E-01, .736356378E-01,
.735667944E-01, .738831162E-01, BM= .140509367 , -.341980867E-01,
.224578637E-02, -.891749049E-03, -.187678510E-03, -.138853327E-03,
-.823327573E-04, -.563217618E-04, -.405385508E-04, -.332245399E-04,
-.177399925E-04, -.672791502E-04, .773137726E-04, AM= 8.09443665 ,
2.04036713 , .413481236 , .137022257 , .603815913E-01,
.317491293E-01, .188409388E-01, .122670084E-01, .863580406E-02,
.654101744E-02, .533758849E-02, .470673293E-02, .451265648E-02, V1=
13.5776100 , RR= 13.3253174 , XR= -1.85566235 , BZ= .643140078
IERR= 0
&END
&TAIOUT
AL= 10.0000000 , RT= 2.00000000 , DF= 1.06949806 , B0=
5000.00000 , GHZ= 8.50000000 , EF= 1.00000000 , 1.10000038 ,
1.00000000 , 1.00000000 , 1.00000000 , .899999976 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , AI0= .444872528E-01, .556690805E-01,
.445367955E-01, .466873683E-01, .488379486E-01, .377056561E-01,
.488874838E-01, .465287566E-01, .467421748E-01, .466963686E-01,
.466940776E-01, .466914922E-01, .466865823E-01, .466949418E-01,
.466851369E-01, .466873683E-01, .466895960E-01, .466797911E-01,
.466881506E-01, .466832407E-01, .466806516E-01, .466783643E-01,
.466325618E-01, .468459725E-01, BM= .897013545E-01, -.220893584E-01,
.153389643E-02, -.583656831E-03, -.115707313E-03, -.882687164E-04,
-.521559996E-04, -.355875382E-04, -.256969215E-04, -.211314182E-04,
-.109161447E-04, -.434395333E-04, .500975148E-04, AM= 12.7181473 ,
3.24121857 , .654892445 , .216522872 , .953212380E-01,
.500889122E-01, .297242701E-01, .193403512E-01, .136210918E-01,
.103177540E-01, .841687620E-02, .742683187E-02, .712139904E-02, V1=
21.4190369 , RR= 14.0956726 , XR= -1.77191162 , BZ= .607410014
IERR= 0
&END
&TAIOUT
AL= 10.0000000 , RT= 2.00000000 , DF= 1.04995728 , B0=
5000.00000 , GHZ= 10.6000004 , EF= 1.00000000 , 1.10000038 ,
1.00000000 , 1.00000000 , 1.00000000 , .899999976 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , AI0= .677233934E-01, .858883262E-01,
.678210258E-01, .715072751E-01, .751935244E-01, .571264774E-01,
.752912760E-01, .711454153E-01, .716135502E-01, .715169907E-01,
.715180635E-01, .715137720E-01, .715051889E-01, .715199709E-01,
.715030432E-01, .715072751E-01, .715113878E-01, .714945793E-01,
.715092421E-01, .715007782E-01, .714964867E-01, .714976788E-01,
.714008808E-01, .718691945E-01, BM= .143674135 , -.379802398E-01,
.354029634E-02, -.111770467E-02, -.135483919E-03, -.140913879E-03,
-.784238655E-04, -.545675284E-04, -.389870111E-04, -.331950869E-04,
-.134392558E-04, -.745957805E-04, .878777209E-04, AM= 8.10222626 ,
2.20501041 , .437428951 , .142914355 , .625991821E-01,
.328071117E-01, .194396973E-01, .126425028E-01, .889838114E-02,

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.674027205E-02, .549839810E-02, .485224649E-02, .464780256E-02,V1=
13.9845362 ,RR= 10.7714005 ,XR= -2.14836407 ,BZ= .757476091
IERR= 0
&END
&TAIOUT
AL= 10.00000000 ,RT= 2.00000000 ,DF= 1.05822468 ,BO=
7200.00000 ,GHZ= 14.00000000 ,EF= 1.00000000 , 1.10000038 ,
1.00000000 , 1.00000000 , 1.00000000 , .899999976 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
1.00000000 , 1.00000000 ,AI0= .560667850E-01, .706872940E-01,
.561389849E-01, .590401143E-01, .619411692E-01, .473926254E-01,
.620134026E-01, .587856770E-01, .591192096E-01, .590497255E-01,
.590488054E-01, .590454116E-01, .590387583E-01, .590501390E-01,
.590369627E-01, .590401143E-01, .590432622E-01, .590300262E-01,
.590414666E-01, .590348169E-01, .590314232E-01, .590305030E-01,
.589610152E-01, .592945553E-01,BM= .116346359 , -.298474319E-01,
.247903890E-02, -.835952815E-03, -.128437387E-03, -.113927192E-03,
-.653440657E-04, -.449940708E-04, -.323111162E-04, -.270379387E-04,
-.123822056E-04, -.585173548E-04, .683706021E-04,AM= 9.91672516 ,
2.62516117 , .524640083 , .172266483 , .756148696E-01,
.396756232E-01, .235246234E-01, .152997077E-01, .107689612E-01,
.815641880E-02, .665655732E-02, .587049127E-02, .563263893E-02,V1=
16.9376221 ,RR= 12.2245407 ,XR= -1.97731590 ,BZ= .694749832
IERR= 0
&END

```


The following two pages list the output from program BMNORM when the output from TAIMI on the preceding four pages is the input.

&NORM

BN= 1.00000000 , -.247506082 , .175510161E-01, -.657714158E-02,
 -.127104414E-02, -.984502723E-03, -.578845153E-03, -.397176016E-03,
 -.284823123E-03, -.235656902E-03, -.120088516E-03, -.486856326E-03,
 .562675064E-03,BMN= 1.14239407 , -.282749712 , .200501941E-01,
 -.751369447E-02, -.145203434E-02, -.112469075E-02, -.661269762E-03,
 -.453731744E-03, -.325380592E-03, -.269213226E-03, -.137188516E-03,
 -.556182116E-03, .642796978E-03,AL= 5.00000000 ,RT= 2.00000000 ,DF
 1.06486034 ,B0= 5000.00000 ,GHZ= 9.00000000 ,RR= 13.3253174
 XR= -1.85566235 ,BZ= .643140078

&END

&NORM

BN= 1.00000000 , -.250785351 , .189296678E-01, -.679238886E-02,
 -.121091818E-02, -.981201651E-03, -.571864657E-03, -.393629540E-03,
 -.281459419E-03, -.234956053E-03, -.113906979E-03, -.493551604E-03,
 .572036486E-03,BMN= 1.14644814 , -.287512600 , .217018984E-01,
 -.778712705E-02, -.138825597E-02, -.112489751E-02, -.655613607E-03,
 -.451276079E-03, -.322678825E-03, -.269365031E-03, -.130588538E-03,
 -.565831549E-03, .655810582E-03,AL= 10.00000000 ,RT= 1.00000000 ,DF
 1.03247261 ,B0= 5000.00000 ,GHZ= 9.00000000 ,RR= 13.3253174
 XR= -1.85566235 ,BZ= .643140078

&END

&NORM

BN= 1.00000000 , -.249424100 , .183684379E-01, -.670336932E-02,
 -.123580988E-02, -.982008874E-03, -.574894482E-03, -.394486124E-03,
 -.283358386E-03, -.234618463E-03, -.116957308E-03, -.490162754E-03,
 .567604322E-03,BMN= 1.14475060 , -.285528600 , .210272968E-01,
 -.767369196E-02, -.141469529E-02, -.112415594E-02, -.658111181E-03,
 -.451588538E-03, -.324374996E-03, -.268579694E-03, -.133887050E-03,
 -.561114633E-03, .649765832E-03,AL= 10.00000000 ,RT= 4.00000000 ,DF
 1.12904644 ,B0= 5000.00000 ,GHZ= 9.00000000 ,RR= 13.3253174
 XR= -1.85566235 ,BZ= .643140078

&END

&NORM

BN= 1.00000000 , -.250510812 , .188152678E-01, -.677313656E-02,
 -.121592684E-02, -.981712248E-03, -.572443474E-03, -.393349910E-03,
 -.282470835E-03, -.234101011E-03, -.115537085E-03, -.491434475E-03,
 .570019474E-03,BMN= 1.14610481 , -.287111878 , .215642825E-01,
 -.776273012E-02, -.139358058E-02, -.112514570E-02, -.656080898E-03,
 -.450820429E-03, -.323741464E-03, -.268304255E-03, -.132417699E-03,
 -.563235721E-03, .653302530E-03,AL= 10.00000000 ,RT= 2.00000000 ,DF
 1.06486034 ,B0= 5000.00000 ,GHZ= 9.00000000 ,RR= 13.3253174
 XR= -1.85566235 ,BZ= .643140078

&END

&NORM

BN= 1.00000000 , -.243386507 , .159831755E-01, -.634654239E-02,
 -.133570097E-02, -.988213811E-03, -.585959060E-03, -.400839839E-03,
 -.288511161E-03, -.236457825E-03, -.126254861E-03, -.478823204E-03,
 .550239114E-03,BMN= 1.13734341 , -.276814222 , .181783736E-01,
 -.721820444E-02, -.151915173E-02, -.112393941E-02, -.666437205E-03,
 -.455892878E-03, -.328136608E-03, -.268933829E-03, -.143595244E-03,
 -.544586685E-03, .625811284E-03,AL= 10.00000000 ,RT= 2.00000000 ,DF
 1.00000000 ,B0= 5000.00000 ,GHZ= 9.00000000 ,RR= 13.3253174
 XR= -1.85566235 ,BZ= .643140078

&END

ENORM

BN= 1.00000000 , -.24625444 , .171000361E-01, -.650666654E-02,
 -.128991692E-02, -.984028680E-03, -.581440283E-03, -.396733405E-03,
 -.286471797E-03, -.235575237E-03, -.121694306E-03, -.484268414E-03,
 .558492262E-03, BMN= 1.14083481 , -.280935705 , .195083171E-01,
 -.742303208E-02, -.147158257E-02, -.112261437E-02, -.663327519E-03,
 -.452607404E-03, -.326817157E-03, -.268752454E-03, -.138833129E-03,
 -.552470330E-03, .637147343E-03, AL= 10.0000000 , RT= 2.00000000 , DF
 1.06949806 , B0= 5000.00000 , GHZ= 8.50000000 , RR= 14.0956726
 XR= -1.77191162 , BZ= .607410014

END

ENORM

BN= 1.00000000 , -.264349818 , .246411525E-01, -.777944177E-02,
 -.942994375E-03, -.980787911E-03, -.545845367E-03, -.379800564E-03,
 -.271357130E-03, -.231044265E-03, -.935398275E-04, -.519201159E-03,
 .611645868E-03, BMN= 1.16407967 , -.307724476 , .286842808E-01,
 -.905589387E-02, -.109772128E-02, -.114171603E-02, -.635407865E-03,
 -.442118384E-03, -.315881567E-03, -.268954085E-03, -.108887878E-03,
 -.604391797E-03, .712004956E-03, AL= 10.0000000 , RT= 2.00000000 , DF
 1.04995728 , B0= 5000.00000 , GHZ= 10.60000004 , RR= 10.7714005
 XR= -2.14836407 , BZ= .757476091

END

ENORM

BN= 1.00000000 , -.256539404 , .213074014E-01, -.718503445E-02,
 -.110392249E-02, -.979206990E-03, -.561633846E-03, -.386725180E-03,
 -.277714804E-03, -.232391787E-03, -.106425374E-03, -.502957962E-03,
 .587647082E-03, BMN= 1.15377426 , -.295983739 , .245839469E-01,
 -.828991085E-02, -.127367815E-02, -.112978462E-02, -.647999113E-03,
 -.446193619E-03, -.320420368E-03, -.268127769E-03, -.122790923E-03,
 -.580300344E-03, .678012380E-03, AL= 10.0000000 , RT= 2.00000000 , DF
 1.05822468 , B0= 7200.00000 , GHZ= 14.00000000 , RR= 12.2245407
 XR= -1.97731590 , BZ= .694749832

END

EBTOFF program

The EBTOFF program runs on the Fusion Energy Division PDP-10 computer at Oak Ridge National Laboratory. It is an interactive program which needs to be run from a graphics terminal. The program prompts for input. The modification made during the work described in this report was to include correction for intercavity cross talk on $W_{\perp}$ signals as an option. A sample output plot for $W_{\perp}$ with this option in effect is given on the next page. On the following pages the FORTRAN listing of EBTOFF, as modified, is given.

W PER. (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=W6)
 (EBTOFF VS) WTS FROM A36AG6.WTS TURN DOWN, EBT I, 50/0, N3, S5, ...
 COMP. FOR CAV. CROSS COUPL. E2 OFF

A33EAF.EB8 EBTOFF VSI 3/11/80-14:27:56
 S_OPRD= 1 FASPRD= 1

```

PROGRAM EBTOFF  !K.H.CARPENTER 15SEP78
C 28JUL80:KHC: VERSION 5 : Added compensation for cavity cross
C coupling for WPER
C 10APR80:KHC: Write of WPER to EBTOFF.DAT
C added.
C 10MAR80:KHC: VERSION 4 : Added weights to W-Per curve,
C for correction of unequal gains.
C 11APR79:KHC: VERSION 3 : Added BEF & AFT values to plot, and
C added looping on curve choice, and
C corrected DO limits on BEF & AFT loops.
C 13FEB79:KHC: VERSION 2 : Added choice of curves 1,2,3 and
C plot at BEF time only if greater than AFT
C Outputs plot or print of W-Per. in ADC units
C as determined from diamagnetic loops on turn-down
C of microwave power.
C Subroutines called are in EBD108 or TEK AG2
C LOAD with EBD108.REL and ADETEK.REL
C
PARAMETER MAX=256,NID=24,MAXP=257
LOGICAL LDIFF
DOUBLE PRECISION DWT
COMMON/CEBB10/IN,FILNA(2),DATIM(4),VERSNO,ISLOPR,IFASPR,IVRD,
1 IFAD,IFPR,ISAMPF,IDPPS,NOWDC,IBUF(342)
COMMON/CADEOU/IPLTU !FOR PLOT UNIT NO. USING TEKADE
DIMENSION IDAR(NID),IFADAT(MAX,NID),PLOTNO(MAXP),XAX(4)
DIMENSION WTS(24),ITIW(4)
DATA WTS/24*1.0/,IWT/0/
DATA IUNIT/50/,XAX/-1.,24.,0.,1./
DATA IVERS/' V5 )'/
C OPEN UNIT 17 FOR ASCII OUTPUT OF RESULTS:
C OPEN(UNIT=17,DEVICE='DSK',FILE='EBTOFF.DAT',ACCESS='APPEND')
C INITIALIZE FOR PLOTS AND TYPE HEADER OUT
1 IOLDCR=0
IPLTU=-1
CALL IHITT(1)
CALL SETBUF(1)
CALL ANIMODE
CALL SLP(1)
5 TYPE 10
10 FORMAT(' EBTOFF V5 - WANT TO ENTER FILE SPEC. OR TIME?:'$)
ACCEPT 20,MODEIN
20 FORMAT(A1)
IF(MODEIN.EQ.'T')GO TO 50
TYPE 30
30 FORMAT(' EBB FORMAT FILE SPEC.: '$)
ACCEPT 40,IDAR
40 FORMAT(24A5)
OPEN(UNIT=IUNIT,DIALOG=IDAR,ACCESS='SEQIN',MODE='IMAGE')
CALL UNIT(IUNIT)
GO TO 80
50 TYPE 60
60 FORMAT(' ENTER MO-DA-YR HR:MI:SE (6G): '$)
ACCEPT 70,MONTH,IDAY,IYEAR,IHR,IMIN,ISEC
70 FORMAT(6G)
CALL RECHD(IUNIT,MONTH,IDAY,IYEAR,IHR,IMIN,ISEC)
C INPUT FILE NOW OPENED - TYPE COMMENTS
80 CALL TYCOM
82 TYPE 85

```

```

55  FORMAT(' PLOT CURVE * 1,2,or 3? (0 TO EXIT, -1 FOR NEW FILE):'$)
    ACCEPT G6,ICURVE
66  FORMAT(G)
    IF(ICURVE.EQ.0.OR.ICURVE.GT.3)STOP* '
    IF(ICURVE.LT.0)GO TO 1
C   SET UP TO READ IN DATA
    IF(ICURVE.EQ.10LDCR)GO TO 100
    IDAR(1)=ICURVE-1
    DO 99 K=2,NID
99   IDAR(K)=IDAR(K-1)+3
C   GO READ IT
    CALL FRMRY(IDAR,NID,N,MAX,IFADAT)
    10LDCR=ICURVE
100  TYPE 110
110  FORMAT(' PLOT DATA FOR SECTOR * (0 TO STOP):'$)
    ACCEPT 70,ISECT
    IF(ISECT.LE.0)GO TO 150 !OUT OF PLOT LOOP
    XAX(2)=N
    XAX(3)=0.
    PLOTNO(1)=N
    DO 120 K=2,N+1
120  PLOTNO(K)=IFADAT(K-1,ISECT)
    CALL NEWPAG
    CALL ANMODE
    CALL SLP(1)
    CALL EIHITT
    CALL CHECK(XAX,PLOTNO)
    CALL DISPLAY(XAX,PLOTNO)
    CALL MOVABS(0,30)
    CALL ANMODE
    WRITE(IPLTU,130)ISECT
130  FORMAT(' SECT.=' ,I3)
    GO TO 100
150  CALL HOME
    CALL ANMODE      !TO DUMP PLOT BUFFER
    TYPE 160
160  FORMAT(' Enter limits of "before" then "after" intervals',
1    ' on time axis - 40'/' (-1 to skip):'$)
    ACCEPT 70,IT1,IT2,IT3,IT4
    IF(IT1.LT.0)GO TO 260
    LDIFF=IT1+IT2.GE.IT3+IT4
    XAX(2)=NID
    XAX(3)=1.
    DO 200 I=1,NID
    BEF=0.
    AFT=0.
    DO 180 J=IT1+1,IT2+1
180  BEF=BEF+IFADAT(J,I)
    DO 190 J=IT3+1,IT4+1
190  AFT=AFT+IFADAT(J,I)
    IF(IT2.GT.IT1)BEF=BEF/(IT2-IT1+1)
    IF(IT4.GT.IT3)AFT=AFT/(IT4-IT3+1)
    PLOTNO(I+1)=BEF-AFT
200  IF(LDIFF)PLOTNO(I+1)=BEF
    PLOTNO(1)=NID
    IF(ICURVE.NE.2)GO TO 202
    IF(IWT.NE.0)GO TO 2050
    TYPE 2010

```

```

2010  FORMAT(' UNWEIGHTED: USE,GET,OR MAKE?:'$)
      ACCEPT 20,IWW
      IF(IWW.EQ.'U'.OR.IWW.EQ.'u')GO TO 202
      IF(IWW.EQ.'M'.OR.IWW.EQ.'m')GO TO 2100
2015  TYPE 2020
2020  FORMAT(' WEIGHT FILE SPEC:$)
      ACCEPT 40,IDAR
      OPEN(UNIT=30,DIALOG=IDAR,ACCESS='SEQIN')
      READ(30,2030)WTS
2030  FORMAT(6G)
      READ(30,2040)DWT,ITIW
2040  FORMAT(1X,A10,7X,215,7X,215)
      IWT=-1
2500  DO 2510 K=1,24
2510  PLOTNO(K+1)=PLOTNO(K+1)*WTS(K)
      GO TO 202
2050  CALL NEWPAG
      CALL ANMODE
      CALL SLP(1)
      TYPE 2060,DWT,WTS
2060  FORMAT(' WEIGHTS FROM ',A10,' ARE:'/4(6F12.4/)/
      1 ' USE,GET,MAKE,or RESET?:'$)
      ACCEPT 20,IWW
      IF(IWW.EQ.'U'.OR.IWW.EQ.'u')GO TO 2500
      IF(IWW.EQ.'M'.OR.IWW.EQ.'m')GO TO 2100
      IF(IWW.EQ.'G'.OR.IWW.EQ.'g')GO TO 2015
C    RESET WEIGHTS TO UNWEIGHTED
      DO 2070 K=1,24
2070  WTS(K)=1.0
      IWT=0
      GO TO 202
C    MAKE WEIGHTS:
2100  IWT=-1
      ENCODE(10,2110,DWT)FILNA
2110  FORMAT(A5,A1,'.WTS')
      OPEN(UNIT=25,FILE=DWT,DEVICE='DSK',ACCESS='SEQOUT')
      DO 2120 K=1,24
      IF(PLOTNO(K+1).LT.10.)WTS(K)=0.
      IF(PLOTNO(K+1).GE.10.)WTS(K)=PLOTNO(2)/PLOTNO(K+1)
2120  CONTINUE
      WRITE(25,2130)WTS,DWT,IT1,IT2,IT3,IT4
2130  FORMAT(4(6F12.4/),1X,A10,' BEF:',215,' AFT:',215)
      ITIW(1)=IT1
      ITIW(2)=IT2
      ITIW(3)=IT3
      ITIW(4)=IT4
      CALL NEWPAG
      CALL ANMODE
      CALL SLP(1)
      TYPE 2140,DWT
2140  FORMAT(' Weights for W-PER written to DSK:',A10/)
      IOLDCR=0
      GO TO 5
202  IF(1CURVE.NE.2)GO TO 2022
      TYPE 310
310  FORMAT(' COMPENSATE FOR CAVITY CROSS COUPLING?(Y OR N):'$)
      ACCEPT 20,ICOMP
      IF(ICOMP.NE.'Y'.AND.ICOMP.NE.'y')GO TO 2022

```



```

230  FORMAT($' PRESSURE (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=W5)'
1    /' (EBTOFF',A5)
      IPLTU=-1
      CALL NEWPAG
      CALL ANMODE
      CALL SLP(1)
      TYPE 235
235  FORMAT(' PRESSURE VS CAVITY OUTPUT TO LPT')
      GO TO 82
240  WRITE(IPLTU,250)IVERS
250  FORMAT($' POWER (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=W5)'
1    /' (EBTOFF',A5)
      IPLTU=-1
      CALL NEWPAG
      CALL ANMODE
      CALL SLP(1)
      TYPE 255
255  FORMAT(' POWER VS CAVITY OUTPUT TO LPT')
      GO TO 82
260  IPLTU=-1
      CALL NEWPAG
      CALL ANMODE
      CALL SLP(1)
      GO TO 82
      END

      SUBROUTINE A10CP(A10,EF)
C      K.H.CARPENTER 28JUL80
C      Same code as A10 except that COMMON/CM1JE1/ removed
C      and BM(13) added to "DIMENSION" statement, and values
C      placed in "DATA" statement for universal normalized correction.
      DIMENSION A10(1),EF(1),BM(13)
      DATA BM/1.145,-0.2863,0.0229,
1      -0.0080,-0.0011,-0.0011,-0.0007,-0.0005,
2      -0.0003,-0.0002,-0.0001,-0.0006,-0.0007/
C      Data values chosen to correct to approximately 5%
C      accuracy PLOTNO output values to those that would be
C      obtained if only flux from each cavity's own annulus
C      linked it.
C      Values are valid to 5% for all reasonable EBT-I/S annuli.
C      SUBROUTINE A10C(A10,EF)
C      K.H.CARPENTER 11JUL80.
C      APPLIES INVERSE MUTUAL INDUCTANCE MATRIX BM TO INPUT WPER SIGNAL.
C      VALUES EF TO GIVE UNFOLDED WPER VALUES A10 (NORMALIZED).
C      NORMALIZATION OF WPER FOR 1' TH CAVITY IS:
C       $WP(1) = (A10(1) - A10(K)) * BV(1) / CPHI / NTURN / MU0 / TWOPI$ 
C      WHERE BV(1) IS "AVERAGE" MAGNETIC FLUX DENSITY OVER ANNULUS,
C      CPHI IS VALUE FLUX LINKING PICKUP COIL IS MULTIPLIED BY TO
C      OBTAIN EF(1), AND NTURN IS TOTAL NO. OF TURNS IN SERIES
C      IN PICKUP COILS ON CAVITY 1. A10(K) IS RESIDUAL VALUE FOR
C      CAVITY WITH NO ANNULUS.
C      FOR DETAILS SEE KHC 9JUL80.
C
C      COMMON/CM1JE1/BM(13),AM(13),V1
C      DIMENSION A10(24),EF(24)
C      MULTIPLIES INPUT VECTOR EF BY MATRIX BM TO OBTAIN OUTPUT
C      VECTOR A10.
C      BM IS A SYMMETRIC, CIRCULANT MATRIX OF DIMENSION 24.

```

```

DO 320 K=2,25
320  PLOTNO(K+25)=PLOTNO(K)
    CALL AIOCP(PLOTNO(2),PLOTNO(27))
2022  IPLTU=-3
    CALL BINITT
    CALL NEWPAG
C  INSERT HERE MODIFICATIONS TO CHANGE SCALE OF PLOT,ETC
    SAVE1=PLOTNO(2)
    SAVE2=PLOTNO(3)
    PLOTNO(2)=0.
    PLOTNO(3)=100.
    CALL CHECK(XAX,PLOTNO)
    PLOTNO(2)=SAVE1
    PLOTNO(3)=SAVE2
    CALL LINE(-1)
    CALL SYMBL(2)
    CALL DISPLAY(XAX,PLOTNO)
    CALL MOVABS(0,500)
    CALL ANMODE
205  WRITE(IPLTU,205) IT1,IT2,IT3,IT4
    FORMAT(' BEF: '/1X,13/1X,13// AFT: '/1X,13/1X,13)
    CALL MOVABS(0,50)
    CALL ANMODE
    CALL WRCOM(IPLTU)
    CALL HOME
    CALL ANMODE
    IF(ICURVE.NE.2)GO TO 220
    IF(IWT.NE.0)WRITE(IPLTU,200) IVERS,DWT
209  FORMAT(' W PER. (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=W5)'
1  // '(EBTOFF',A5,' WTS FROM ',A10)
    IF(IWT.EQ.0)WRITE(IPLTU,210) IVERS
210  FORMAT(' W PER. (IN ADC COUNTS) VS. CAVITY NO. (1=N1, 24=W6)'
1  // '(EBTOFF',A5)
    IF(ICOMP.EQ.'Y'.OR.ICOMP.EQ.'y')WRITE(IPLTU,330)
330  FORMAT(10X,' COMP.FOR CAV.CROSS COUPL. ')
    IPLTU=-1
    CALL NEWPAG
    CALL ANMODE
    CALL SLP(1)
    TYPE 215
215  FORMAT(' W PER VS CAVITY OUTPUT TO LPT')
    WRITE(17,3010) (PLOTNO(K),K=2,25)
3010  FORMAT(/1H1,' EBTOFF-V4 W PER (in ADC counts) N1-N6,'
1  , ' E1-E6, S1-S6, W1-W6'//4(6F12.4/))
    IF(ICOMP.EQ.'Y'.OR.ICOMP.EQ.'y')WRITE(17,340)
340  FORMAT(' COMPENSATED FOR CAVITY CROSS COUPLING')
    WRITE(17,3015) IT1,IT2,IT3,IT4
3015  FORMAT(' Samples averaged - BEF:',215,' AFT:',215/)
    IF(IWT.NE.0)WRITE(17,3020)DWT,ITIW
3020  FORMAT(' Weighted by ',A10,' BEF:',215,' AFT:',215/)
    WRITE(17,3025)
3025  FORMAT(' Data file I.D. and comments:')
    CALL WRCOM(17)
    TYPE 3030
3030  FORMAT(' W PER WRITTEN TO EBTOFF.DAT')
    GO TO 82
220  IF(ICURVE.NE.1)GO TO 240
    WRITE(IPLTU,230) IVERS

```

```

DO 100 I=1,24
N=MOD(I+12,24)
IF(N.EQ.0)N=24
A10(I)=BM(1)*EF(I)+BM(13)*EF(N)
DO 50 J=2,12
  N1=MOD(I+J-1,24)
  IF(N1.EQ.0)N1=24
  N2=MOD(25+I-J,24)
  IF(N2.EQ.0)N2=24
  A10(I)=A10(I)+BM(J)*(EF(N1)+EF(N2))
50  CONTINUE
100 CONTINUE
RETURN
END

```

FLDEQ program

The FLDEQ program was used to provide the simulation of the NBT Hall probe versus perpendicular energy data as well as to provide the simulated data for EBT diamagnetic field components as functions of ring parameters. The main program and all subroutines are contained in a single FORTRAN file. FLDEQ is documented with comment lines in the listing. The program prompts for input. A sample terminal session showing the input dialog and the resultant output produced is given on the next page. The program listing then follows.

```

R;

.LOAD FLDEQ(NOMAP START
EXECUTION BEGINS...
WHICH PARAMETER DO YOU WISH TO VARY ? : L=LENGTH, R=MEAN RADIUS, T=THICKNESS :
.L
ENTER INITIAL VALUES OF THE PARAMETERS : TOTAL LENGTH, MEAN RADIUS, THICKNESS, AND CURVE
?
.1 13.33 1 .937
ENTER THE UPPER LIMIT OF THE PARAMETER BEING VARIED:
?
.20
HOW MANY VALUES DO YOU WANT CALCULATED (UP TO 100) ?
?
.20
ENTER FIELD POINT COORDINATES X,R (IN CENTIMETERS)
?
.1.5 25.
ENTER ANNULUS OFFSET VALUE :
?
.-1.856
INCLUDE ADJACENT CAVITY EFFECTS ? (Y OR N):
.Y
DO YOU WANT ANOTHER CASE ? (Y OR N):
.N
R;

```

TY FILE FI08F001

(X,R)=(1.50, 25.00) OFFSET= -1.856 ADJACENT INCLUDED ? : Y
 BZMAX= 0.047467 BRMAX= -0.010009 APMAX= -2.074389

LENGTH	RADIUS	THICKNESS	CR	BZ	BR	AP
1.000	13.330	1.000	0.937	0.083843	0.110523	0.054503
2.000	13.330	1.000	0.937	0.166958	0.219387	0.108919
3.000	13.330	1.000	0.937	0.248625	0.324994	0.163166
4.000	13.330	1.000	0.937	0.328171	0.425862	0.217159
5.000	13.330	1.000	0.937	0.404952	0.520668	0.270816
6.000	13.330	1.000	0.937	0.478383	0.608288	0.324075
7.000	13.330	1.000	0.937	0.547952	0.687811	0.376853
8.000	13.330	1.000	0.937	0.613222	0.758586	0.429089
9.000	13.330	1.000	0.937	0.673811	0.820196	0.480735
10.000	13.330	1.000	0.937	0.729453	0.872421	0.531734
11.000	13.330	1.000	0.937	0.779936	0.915253	0.582039
12.000	13.330	1.000	0.937	0.825133	0.948927	0.631607
13.000	13.330	1.000	0.937	0.864963	0.973691	0.680430
14.000	13.330	1.000	0.937	0.899425	0.990067	0.728498
15.000	13.330	1.000	0.937	0.928611	0.998665	0.775741
16.000	13.330	1.000	0.937	0.952603	1.000000	0.822190
17.000	13.330	1.000	0.937	0.971540	0.994709	0.867831
18.000	13.330	1.000	0.937	0.985615	0.983473	0.912676
19.000	13.330	1.000	0.937	0.995027	0.966922	0.956724
20.000	13.330	1.000	0.937	1.000000	0.945676	1.000000

R;

```

C PROGRAM FLDE2: F.ZYKAN 24JUL80 FLD00
CZ F.W.ZYKAN 28AUG80 : OUTPUT NORMALIZED ; MAXIMUM FIELD FLD00
CZ VALUES LISTED . FLD00
CK K.H.CARPENTER 08AUG80 : R1S INSERTED IN COMMON/CFB/ IN MAIN PROG. FLD00
CK OUTPUT CHANGED TO UNIT 8; ALTERNATE OUTPUT LOOP INSERTED-AS FLD00
CK COMMENTS BEGINNING CK FLD00
C FLD00
C THIS PROGRAM WILL CALCULATE THE RADIAL AND AXIAL B-FIELDS FLD00
C DUE TO TWO COAXIAL CURRENT CYLINDERS WHOSE CENTERS ARE AT THE FLD00
C REFERENCE, OR PRIMARY ORIGIN. THE PROGRAM IS USER-INTERACTIVE, FLD00
C AND IS DESIGNED FOR USE ON THE IBM VIRTUAL MACHINE/CMS TERMI- FLD00
C NALS. FLD00
C THE PROGRAM PROMPTS THE USER FOR THE INPUT DATA, WHICH FLD00
C CONSISTS OF THE CYLINDER (OR ANNULUS) LENGTH, RADIUS, THICKNESS, FLD00
C CURRENT RATIO, AND OFFSET. THESE TERMS REPRESENT THE FOLLOWING : FLD00
C LENGTH---THE TOTAL LENGTH OF THE CYLINDERS IN CM. FLD00
C RADIUS---THE ARITHMETIC MEAN OF THE RADII OF THE TWO FLD00
C CYLINDERS IN CM. FLD00
C THICKNESS---THE DIFFERENCE BETWEEN THE RADII OF THE TWO FLD00
C CYLINDERS IN CM. FLD00
C CURRENT RATIO---THIS IS THE RATIO OF THE INNER CYLINDER FLD00
C CURRENT DENSITY TO THE OUTER CYLINDER FLD00
C CURRENT DENSITY. FLD00
C OFFSET---THE DISTANCE THAT THE ANNULUS IS DISPLACED FROM FLD00
C THE CENTER OF THE EBT CAVITY, DUE TO THE NON- FLD00
C UNIFORMITY OF THE MAGNETIC FIELD WHICH THE ELECTRONS FLD00
C MOVE THROUGH, IN CM. FLD00
C THE USER MUST ALSO CHOOSE WHICH PARAMETER IS TO BE VARIED, FLD00
C WHETHER IT IS LENGTH, MEAN RADIUS, OR THICKNESS, AND ALSO HOW FLD00
C MANY VALUES ARE TO BE CALCULATED, ALONG WITH THE UPPER LIMIT FLD00
C OF THE PARAMETER BEING VARIED. THE PROGRAM WILL PROMPT FOR EACH. FLD00
C THE USER MUST ALSO DECIDE WHETHER OR NOT TO INCLUDE THE EFFECTS FLD00
C OF TWO SIMILAR ANNULI WHICH ARE ON EITHER SIDE OF THE 'CENTER' FLD00
C ANNULUS, AND IN A CONFIGURATION LIKE THE CAVITIES IN 'EBT'(15- FLD00
C DEGREES OFF OF A LINE FROM THE CENTER OF 'EBT' TO THE CENTER FLD00
C OF THE FIRST ANNULUS, AND EACH 150 CM. AWAY FROM THE CENTER OF FLD00
C THE 'EBT' MACHINE). FLD00
C THE FINAL PIECE OF INFORMATION NECESSARY FOR THE CALCULATIONS FLD00
C IS THE POINT AT WHICH THE USER WANTS THE FIELDS CALCULATED. FLD00
C THE OUTPUT IS DISPLAYED ON THE CRT TERMINAL, AND MUST EITHER FLD00
C BE COPIED OR PRINTED FOR A HARD COPY LISTING OF THE DATA OUTPUT. FLD00
C FLD00
C THE PROGRAM USES A SINGLE-PRECISION ADAPTIVE SIMPSON'S RULE FLD00
C FOR INTEGRATION, AND ALL ELLIPTIC INTEGRALS ARE DONE IN-LINE. FLD00
C FLD00
C FLD00
COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPRSQ,RMR1SQ FLD00
DIMENSION BZZ(100),BRR(100),AL(100),ANMR(100),APP(100) FLD00
1,ATHK(100) FLD00
C FLD00
C INITIALIZATION. FLD00
DATA IL,IR,IT,IY/'L','R','T','Y'/ FLD00
C15=COS(.26179938) FLD00
S15=SIN(.26179938) FLD00
C FLD00
C AMR IS THE DISTANCE FROM THE PHYSICAL CENTER OF THE ANNULI FLD00
C TO THE CENTER OF 'EBT'. FLD00

```

```

      AMR=150
10     IVL=0
      IVR=0
      IVT=0
C      INPUT OF PARAMETERS.
15     WRITE(6,20)
20     FORMAT(' WHICH PARAMETER DO YOU WISH TO VARY ? : L=LENGTH, R=MEAN R
1ADIIUS, T=THICKNESS :')
      READ(5,30)IVAR
30     FORMAT(A1)
C      SETTING UP INCREMENTING 'FLAG' SO THAT PROPER PARAMETER
C      IS INCREMENTED.
      IF(IVAR.NE.II.AND.IVAR.NE.IR.AND.IVAR.NE.IT)GOTO15
      IF(IVAR.EQ.II)IVL=1
      IF(IVAR.EQ.IR)IVR=1
      IF(IVAR.EQ.IT)IVT=1
      WRITE(6,40)
40     FORMAT(' ENTER INITIAL VALUES OF THE PARAMETERS : TOTAL LENGTH, ME
1AN RADIUS, THICKNESS,      AND CURRENT RATIO :')
      READ(5,*)AL(1),ANMR(1),ATHK(1),CR
      WRITE(6,60)
60     FORMAT(' ENTER THE UPPER LIMIT OF THE PARAMETER BEING VARIED:')
      READ(5,*)FINISH
      WRITE(6,80)
80     FORMAT(' HOW MANY VALUES DO YOU WANT CALCULATED (UP TO 100) ?')
      READ(5,*)NMPT
      WRITE(6,100)
100    FORMAT(' ENTER FIELD POINT COORDINATES X,R (IN CENTIMETERS)')
      READ(5,*)XL,RLL
      WRITE(6,110)
110    FORMAT(' ENTER ANNULUS OFFSET VALUE :')
      READ(5,*)OFF
      WRITE(6,120)
120    FORMAT(' INCLUDE ADJACENT CAVITY EFFECTS ? (Y OR N):')
      READ(5,130)NEI
130    FORMAT(A1)
      IF(NMPT.LE.1)GOTO135
C      CALCULATING INCREMENTAL VALUE FOR APPROPRIATE PARAMETER.
      IF(IVAR.EQ.II)DEL=(FINISH-AL(1))/(NMPT-1)
      IF(IVAR.EQ.IR)DEL=(FINISH-ANMR(1))/(NMPT-1)
      IF(IVAR.EQ.IT)DEL=(FINISH-ATHK(1))/(NMPT-1)
C      ALL FIELD OUTPUT DATA IS STORED IN ARRAYS.
C      THIS PORTION SETS UP FIRST VALUES TO BE CALCULATED.
C
C      INITIALIZE 'MAXIMUM' REGISTERS.
      BZMAX=0.
      BRMAX=0.
      APMAX=0.
135    N=1
140    AL2=AL(N)/2.
      AR1=ANMR(N)-ATHK(N)/2.
      AR2=ANMR(N)+ATHK(N)/2.
CC
CC      CALCULATE FIELD DUE TO CENTER ANNULUS
CC

```

```

C      'RL' IS THE RADIAL DISTANCE OF THE POINT TO THE ANNULUS CENTERFLD01
C      ADJUSTED FOR THE 'OFFSET' VALUE.                                FLD01
      RL=RLL-OFF                                                         FLD01
C      'SXC' IS USED TO OBTAIN THE CORRECT SIGN FOR THE COMPONENTS    FLD01
C      REGARDLESS OF POINT'S LOCATION IN 'QUADRANT' ABOUT THE ANNULUSFLD01
      SXC=SIGN(1.,XL)*SIGN(1.,RL)                                       FLD01
C 1    THE POINT, (X,R), AND RADIUS, R1, ARE SET UP FOR CALCULATION    FLD01
      X=XL                                                                FLD01
      R=ABS(RL)                                                           FLD01
C      INNER CURRENT-SHEET RADIUS (AR1).                                FLD01
      R1=AR1                                                             FLD01
C      FBI CALCULATES THE AXIAL B-FIELD COMPONENT                      FLD01
      CALL FBI                                                            FLD01
      BZ=CR*FB                                                            FLD01
C      FBR CALCULATES THE RADIAL B-FIELD COMPONENT                    FLD01
      CALL FBR                                                            FLD01
      BR=FB*CR                                                            FLD01
C      AS1 CALCULATES THE MAGNETIC VECTOR POTENTIAL COMPONENT          FLD01
      CALL AS1                                                            FLD01
      AP=FB*CR*R*2.                                                       FLD01
C
C      SIMILARLY, THE OUTER SHEET VALUES (BZ,BR,&AP) ARE CALCULATED. FLD01
C
C      OUTER CURRENT-SHEET RADIUS (AR2).                                FLD01
      R1=AR2                                                             FLD01
      CALL FBI                                                            FLD01
      BZ=BZ-FB                                                            FLD01
      CALL FBR                                                            FLD01
      BR=BR-FB                                                            FLD01
      CALL AS1                                                            FLD01
      AP=AP-FB*2.*R                                                       FLD01
      BR=BR*SXC                                                           FLD01
C      ADJ. VALUES ARE NOW SET TO ZERO(IN CASE ADJACENT NOT CONSIDERED). FLD01
      BNR=0.                                                             FLD01
      BNZ=0.                                                             FLD01
      ANP=0.                                                             FLD01
C      CHECK TO SEE IF ADJACENT ANNULI ARE TO BE CONSIDERED.          FLD01
      IF(NEI.NE.IY)GOTO130                                              FLD01
CC
CC      CALCULATE ADJACENT ANNULUS EFFECTS                               FLD01
CC
CC      FIRST ADJACENT ANNULUS :                                         FLD01
C
C      OFFSET EFFECT IS NOW INCLUDED.                                    FLD01
      RMA=AMR+OFF                                                         FLD01
C      A COORDINATE-TRANSFORMATION IS PERFORMED TO CORRECTLY          FLD01
C      INCLUDE THE EFFECTS OF THE ADJACENT ANNULI:                     FLD01
      RP=RL+RMA                                                           FLD01
      R1=AR1                                                             FLD01
      R=RP*C15+XL*S15-RMA                                                FLD01
      X=XL*C15-RP*S15                                                    FLD01
      SX=SIGN(1.,X)*SIGN(1.,R)                                           FLD01
      SA=SIGN(1.,R)                                                       FLD01
      R=ABS(R)                                                            FLD01
C      AS BEFORE, THE FIELDS ARE CALCULATED WITH THE PROPER VALUES    FLD01

```



```

C          FOR THE INNER AND OUTER CURRENT SHEETS OF ONE ADJACENT ANNULUSFLD01
CALL FBI                                       FLD01
BNZ=FB*CR                                    FLD01
CALL FBR                                       FLD01
BNR=FB*CR*SX                                 FLD01
CALL AS1                                       FLD01
ANP=FB*CR*R*2.*SA                           FLD01
R1=AR2                                        FLD01
CALL FBI                                       FLD01
BNZ=BNZ-FB                                    FLD01
CALL FBR                                       FLD01
BNR=BNR-FB*SX                                 FLD01
CALL AS1                                       FLD01
ANP=ANP-FB*2.*R*SA                           FLD01
C          TRANSFORMED COMPONENT VALUES ADDED TO THE CENTER-ANNULUS FIELD FLD01
BZ=BZ+BNZ*C15+BNR*S15                       FLD01
BR=BR+BNR*C15-BNZ*S15                       FLD01
AP=AP+ANP                                     FLD01
CC                                              FLD01
CC          SECOND ADJACENT ANNULUS :          FLD01
CC                                              FLD01
C          AS FOR THE FIRST ADJACENT ANNULUS, THE TRANSFORMED FIELD FLD01
C          COMPONENTS FROM THE SECOND ADJACENT ANNULUS ARE ADDED TO FLD01
C          THE FIELD TOTALS:                  FLD01
R=R-XL*S15*2.                                FLD01
X=RP*S15+XL*C15                              FLD01
R1=AR1                                        FLD01
SA=SIGN(1.,R)                                FLD01
SX=SIGN(1.,X)*SIGN(1.,R)                    FLD01
R=ABS(R)                                     FLD01
CALL FBI                                       FLD01
BNZ=FB*CR                                    FLD01
CALL FBR                                       FLD01
BNR=FB*CR*SX                                 FLD01
CALL AS1                                       FLD02
ANP=FR*CR*R*2.*SA                           FLD02
R1=AR2                                        FLD02
CALL FBI                                       FLD02
BNZ=BNZ-FB                                    FLD02
CALL FBR                                       FLD02
BNR=BNR-FB*SX                                 FLD02
CALL AS1                                       FLD02
ANP=ANP-FB*2.*R*SA                           FLD02
CC                                              FLD02
CC          FINAL SUM OF FIELDS                FLD02
CC                                              FLD02
C          ARRAY STORAGE OF SUMS:              FLD02
150 BZZ(N)=BZ+BNZ*C15-BNR*S15                 FLD02
    BRR(N)=(BR+BNR*C15+BNZ*S15)*SXC          FLD02
    APP(N)=AP+ANP                             FLD02
C          COMPARE TO PREVIOUS MAX.            FLD02
IF(ABS(BZMAX).LT.ABS(BZZ(N)))BZMAX=BZZ(N)    FLD02
IF(ABS(BRMAX).LT.ABS(BRR(N)))BRMAX=BRR(N)    FLD02
IF(ABS(APMAX).LT.ABS(APP(N)))APMAX=APP(N)    FLD02
C          LAST SET TO CALCULATE ?            FLD02

```

```

      IF(N.GE.NMPT)GOTO160
C      IF NOT, INCREMENT APPROPRIATE VALUES AND CALCULATE NEW
C      FIELD COMPONENTS:
      N=N+1
      AL(N)=AL(N-1)+IVL*DEL
      ANMR(N)=ANMR(N-1)+IVR*DEL
      ATHK(N)=ATHK(N-1)+IVT*DEL
      GOTO140
C      NORMALIZING SCHEME.
160    DO 161 I=1,NMPT
      BZZ(I)=BZZ(I)/BZMAX
      BRR(I)=BRR(I)/BRMAX
161    APP(I)=APP(I)/APMAX
CC
CC      OUTPUT LOOP
CC      SETS UP A TABLE OF OUTPUT FOR ALL INPUT AND OUTPUT VALUES.
CK
      WRITE(8,162)XL,RLL,OFF,NEI
162    FORMAT(/' (X,R)=(',F7.2,',',F7.2,')',3X,'OFFSET=',F7.3,
1'      ADJACENT INCLUDED ? : ',A1)
      WRITE(8,165)BZMAX,BRMAX,APMAX
165    FORMAT(/5X,'BZMAX=',F10.6,4X,'BRMAX=',F10.6,4X,'APMAX=',F10.6)
      WRITE(8,170)
170    FORMAT(/'  LENGTH      RADIUS  THICKNESS    CR          BZ          BR
1      AP')
      DO 190 N=1,NMPT
      WRITE(8,185)AL(N),ANMR(N),ATHK(N),CR,BZZ(N),BRR(N),APP(N)
185    FORMAT(4(F8.3,1X),3(F10.6,1X))
190    CONTINUE
CK
CK160  WRITE(8,162)XL,RLL,OFF,NEI
CK162  FORMAT(/' (X,R)=(',F7.2,',',F7.2,')',3X,'OFFSET=',F7.3,
CK    1'      ADJACENT INCLUDED ? : ',A1)
CK    WRITE(8,170)
CK170  FORMAT(/'  LENGTH      RADIUS  THICKNESS    CR          BZ          BR
CK    1      APhi')
CK    WRITE(8,185)(AL(N),ANMR(N),ATHK(N),CR,BZZ(N),BRR(N),APP(N),
CK    1 N=1,NMPT)
CK185  FORMAT(0PF8.3,3F9.3,1P3E13.3)
C      ASKS IF USER WANTS ANOTHER CASE:
      WRITE(6,200)
200    FORMAT(' DO YOU WANT ANOTHER CASE ? (Y OR N):')
      READ(5,130)ID
      IF(ID.EQ.IY)GOTO10
      END
C
C
C      SUBROUTINE FBI
C      CALCULATES INTEGRAL FB OF KHC 20OCT76 USING SASIMP
C      EXTERNAL FBFUN
C      COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ
C      X=ABS(X)
C      ET=1.E-4
C      N=1
C      RS=R*R

```

```

R1S=R1*R1
R1R4=4.*R*R1
RPR1SQ=(R+R1)**2
RMR1SQ=(R-R1)**2
IF(X.LT.AL2)GO TO 10
FB=SASIMP(-AL2,AL2,ET,M,N,FBFUN)
RETURN
10 FB=SASIMP(-AL2,X,ET,M,N,FBFUN)+SASIMP(X,AL2,ET,M,N,FBFUN)
RETURN
END

FUNCTION FBFUN(Z)
C MODIFIED 30MAY77 TO CALCULATE K & E IN-LINE. IN-LINE CODE
C FROM ROUTINE CEIB. (REPLACES CALLS TO CEL2)
COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ
DATA P/1.E-5/,PI2/1.570796326794897/
XZS=(X-Z)**2
DENM=RPR1SQ+XZS
AK2=R1R4/DENM
C CALCULATE RK=K(AK2) AND RE=E(AK2)
IF((AK2.LT.0.).OR.(AK2.GT..9999999))GOTO55
A=1.
B=SQRT(1.-AK2)
C=.5*AK2
CM=.25
10 T=A-B
IF(T.LE.P)GO TO 20
A1=A
A=.5*(A+B)
B=SQRT(A1*B)
C=C+CM*T*T
CM=CM*2.
GO TO 10
20 RK=PI2/A
RE=RK-RK*C
FBFUN=(RK+RE*(R1S-RS-XZS)/(RMR1SQ+XZS))/SQRT(DENM)
RETURN
55 WRITE(6,60)
60 FORMAT(' *** BAD ARGUMENT TO K IN FBI ***')
STOP
END

C
C
SUBROUTINE FBR
C MODIFICATION OF FBI TO CALCULATED RADIAL FIELD COMPONENT.
C CALCULATES INTEGRAL FB OF KHC 20OCT76 USING SASIMP
EXTERNAL FRFUN
COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ
X=ABS(X)
ET=1.E-4
N=1
RS=R*R
R1S=R1*R1
R1R4=4.*R*R1
RPR1SQ=(R+R1)**2

```

```

RMR1SQ=(R-R1)**2
IF(X.LT.AL2)GO TO 10
AX=.0-AL2
FB=SASIMP(AX,AL2,ET,M,N,FRFUN)
RETURN
10 AX=.0-AL2
FB=SASIMP(AX,X,ET,M,N,FRFUN)+SASIMP(X,AL2,ET,M,N,FRFUN)
RETURN
END
CC
FUNCTION FRFUN(Z)
C MODIFIED 30MAY77 TO CALCULATE K & E IN-LINE. IN-LINE CODE
C FROM ROUTINE CEIB. (REPLACES CALLS TO CEL2)
COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ
DATA P/1.E-5/,PI2/1.570796326794897/
XZ=X-Z
XZS=XZ*XZ
DENM=RPR1SQ+XZS
AK2=R1R4/DENM
C CALCULATE RK=K(AK2) AND RE=E(AK2)
IF((AK2.LT.0.).OR.(AK2.GT..999999))GOTO55
A=1.
B=SQRT(1.-AK2)
C=.5*AK2
CM=.25
10 T=A-B
IF(T.LE.P)GO TO 20
A1=A
A=.5*(A+B)
B=SQRT(A1*B)
C=C+CM*T*T
CM=CM*2.
GO TO 10
20 RK=PI2/A
RE=RK-RK*C
FRFUN=XZ*((.0-RK)+RE*(R1S+RS+XZS)/(RMR1SQ+XZS))/(R*SQRT(DENM))
RETURN
55 WRITE(6,60)
60 FORMAT(' *** BAD ARGUMENT TO K IN FBR ***')
STOP
END
C
C
FUNCTION SASIMP(A1,B,EE,M,N,FUN)
C This is a SINGLE PRECISION version of ASIMP
C PROGRAM AUTHOR K. HILLSTROM
C ARGONNE NATIONAL LABORATORY
C CHICAGO,ILL.
C
C THIS VERSION HAS BEEN MODIFIED TO ELIMINATE ASIMP'S CHANGING
C OF ANY OF ITS ARGUMENTS EXCEPT M. IF A1=B ON CALL, THEN
C A VALUE OF ZERO IS RETURNED IMMEDIATELY, AND M = 0.
C
REAL
& SASIMP,A1,B,EP,FUN,A,EPS,ABSAR,EST,FA,FM,FB,DX,SX,

```

>	F1,F2,FBP,EST2,NRTR,EST1,SUM,DAFT,ESUM,TSUM,DA,DIFF	FLD03
	REAL AEST2,FTST,FMAX,AF1,AF2,AEST1,DELTA,AEST	FLD03
	DIMENSION F2(30),FBP(30),EST2(30),NRTR(30)	FLD03
	DIMENSION AEST2(30),FTST(3)	FLD03
C	THE PARAMETER SETUP FOR THE INITIAL CALL	FLD03
	IF((B-A1).EQ.0.E0)GO TO 200	FLD03
	EP=EE	FLD03
	IF (N.LE.0) GO TO 40	FLD03
	IF (N.GT.3) GO TO 50	FLD03
	A=A1	FLD03
	EPS=EP*15.0E0	FLD03
	ESUM=0.0E0	FLD03
	TSUM=0.0E0	FLD03
	LVL=1	FLD03
	DA=B-A	FLD04
	FA=FUN(A)	FLD04
	FM=FUN((A+B)*0.5E0)	FLD04
	FB=FUN(B)	FLD04
	M=3	FLD04
	FMAX=ABS(FA)	FLD04
	FTST(1)=FMAX	FLD04
	FTST(2)=ABS(FM)	FLD04
	FTST(3)=ABS(FB)	FLD04
	DO 10 I=2,3	FLD04
	IF (FMAX.GE.FTST(I)) GO TO 10	FLD04
	FMAX=FTST(I)	FLD04
10	CONTINUE	FLD04
	EST=(FA+4.0E0*FM+FB)*DA/6.0E0	FLD04
	ABSAR=(FTST(1)+4.0E0*FTST(2)+FTST(3))*DA/6.0E0	FLD04
	AEST=ABSAR	FLD04
C	1=RECUR	FLD04
20	DX=DA/(2.0E0**LVL)	FLD04
	SX=DX/6.0E0	FLD04
	F1=FUN(A+0.5E0*DX)	FLD04
	F2(LVL)=FUN(A+1.5E0*DX)	FLD04
	EST1=3X*(FA+4.0E0*F1+FM)	FLD04
	FBP(LVL)=FB	FLD04
	EST2(LVL)=SX*(FM+4.0E0*F2(LVL)+FB)	FLD04
	SUM=EST1+EST2(LVL)	FLD04
	FTST(1)=ABS(F1)	FLD04
	FTST(2)=ABS(F2(LVL))	FLD04
	FTST(3)=ABS(FM)	FLD04
	AEST1=SX*(ABS(FA)+4.0E0*FTST(1)+FTST(3))	FLD04
	AEST2(LVL)=SX*(FTST(3)+4.0E0*FTST(2)+ABS(FB))	FLD04
	ABSAR=ABSAR AEST+AEST1+AEST2(LVL)	FLD04
	M=M+2	FLD04
	GO TO (60,30,70),N	FLD04
30	DELTA=ABSAR	FLD04
	GO TO 90	FLD04
40	PRINT 10000	FLD04
	RETURN	FLD04
50	PRINT 10100	FLD04
	RETURN	FLD04
60	DELTA=1.0E0	FLD04
	GO TO 90	FLD04

```

70 DO 80 I=1,2                                FLD04
    IF (FMAX.GE.FTST(I)) GO TO 80             FLD04
    FMAX=FTST(I)                             FLD04
80 CONTINUE                                  FLD04
    DELTA=FMAX                               FLD04
90 DIFF=ABS(EST-SUM)                          FLD04
    DAFT= (EST-SUM)/15.0E0                   FLD04
    IF (DIFF-EPS*DELTA) 110,110,100          FLD04
100 IF (LVL-30) 140,120,120                  FLD04
110 IF (LVL-1) 120,140,120                  FLD04
C 2=UP                                        FLD04
120 A=A+2.0E0*DX                             FLD04
130 LVL=LVL-1                                FLD04
    ESUM=ESUM+DAFT                           FLD04
    L=NRTR(LVL)                              FLD04
    TSUM=TSUM+SUM                            FLD04
    GO TO (160,170),L                        FLD04
C 11=R1,12=R2                               FLD04
140 NRTR(LVL)=1                              FLD04
    EST=EST1                                 FLD04
    AEST=AEST1                              FLD04
    FB=FM                                    FLD04
    FM=F1                                    FLD04
    EPS=EPS/2.0E0                           FLD04
150 LVL=LVL+1                                FLD04
    GO TO 20                                 FLD04
160 NRTR(LVL)=2                              FLD04
    FA=FB                                    FLD04
    FM=F2(LVL)                              FLD04
    FB=FBP(LVL)                             FLD04
    EST=EST2(LVL)                           FLD04
    AEST=AEST2(LVL)                         FLD04
    GO TO 150                               FLD04
170 EPS=2.0E0*EPS                           FLD04
    SUM=0.0E0                               FLD04
    IF (LVL-1) 180,180,130                  FLD04
180 SASIMP=TSUM                              FLD04
    A=ABS(ESUM)                             FLD04
    EP=DIFF/DELTA                           FLD04
    IF (A.GE.EP) GO TO 190                  FLD04
    SASIMP=SASIMP-ESUM                      FLD04
190 RETURN                                  FLD04
200 SASIMP = 0.E0                            FLD04
    M = 0                                   FLD04
    RETURN                                  FLD04
10000 FORMAT(' ERROR RETURN-N.LE.0')        FLD04
10100 FORMAT(' ERROR RETURN-N.GT.3')        FLD04
END                                           FLD04
C                                           FLD04
C                                           FLD04
C SUBROUTINE AS1                             FLD04
C THIS SUBROUTINE CALCULATES INTEGRAL AS1 OF KHC 14DEC76. FLD04
C ARGUMENTS ARE IN COMMON/CFB/; RETURNED VALUE IS IN FB. FLD04
C EXTERNAL ASFUN                             FLD04
C COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ FLD04

```

```

      ET=1.E-4
      N=1
      XU=X+AL2
      XL=X-AL2
      RR=R/R1
      IF(RR.LT.1.E-3)GOTO40
      COEF=SQRT(R1/R)/R
      R1R4=4.*R*R1
      RPR1SQ=(R+R1)**2
      IF(XL.LT.0.)( ) TO 10
      FB=SASIMP(XL,XU,ET,NFUNCT,N,ASFUN)*COEF
C10    FB=(SASIMP(XL,0.,ET,M,N,ASFUN)+SASIMP(0.,XU,ET,M,N,ASFUN))*COEF
      RETURN
      10    IF(ABS(1.-RR).LT.1.E-3)GOTO30
      FB=2.*COEF*SASIMP(XL,0.,ET,NFUNCT,N,ASFUN)
      20    FB=FB+COEF*SASIMP(-XL,XU,ET,NFUNCT,N,ASFUN)
      RETURN
      30    R1R4=R1*R1*1.001*4.
      RPR1SQ=(R1*(2.001))**2
      FB=COEF*SASIMP(XL,0.,ET,NFUNCT,N,ASFUN)
      R1R4=R1*R1*0.999*4.
      RPR1SQ=(R1*(1.999))**2
      FB=FB+COEF*SASIMP(XL,0.,ET,NFUNCT,N,ASFUN)
      GOTO20
      40    R1S=R1*R1
      FB=(3.141592653589793D0/4.)*(XU/SQRT(R1S+XU*XU)
      1    -XL/SQRT(R1S+XL*XL))
      END

      FUNCTION ASFUN(Z)
C      MODIFIED 30MAY77 TO CALC. K & E IN-LINE.IN-LINE CODE
C      FROM ROUTINE CEIB. (REPLACES CALLS TO CEL2)
      COMMON/CFB/FB,R,X,R1,AL2,RS,R1S,R1R4,RPR1SQ,RMR1SQ
      DATA P/1.E-5/,PI2/1.570796326794897/
      AK2=R1R4/(RPR1SQ+Z*Z)
      AK=SQRT(AK2)
C      CALCULATE RK=K(AK2) AND RE=E(AK2)
      IF((AK2.LT.0.).OR.(AK2.GT..9999999))GOTO55
      A=1.
      B=SQRT(1.-AK2)
      C=.5*AK2
      CM=.25
      10    T=A-B
      IF(T.LE.P)GOTO20
      A1=A
      A=.5*(A+B)
      B=SQRT(A1*B)
      C=C+CM*T*T
      CM=CM*2
      GOTO10
      20    RK=PI2/A
      RE=RK-RK*C
C      USE RK & RE TO GET ASFUN:
      ASFUN-((1-AK2/2.)*RK-RE)/AK
      RETURN

```

55	WRITE(6,60)	FLD05
60	FORMAT(' BAD ARG. TO K IN AS1')	FLD05
	STOP	FLD05
	END	FLD05

EQUIL program

The EQUIL FORTRAN code produces the MHD equilibrium for a two-dimensional bumpy cylinder. The code of Hedrick¹¹ has been modified. The majority of changes are in the main program and subroutine BATS, hence only these are listed here. Following this listing we have included the outputs from the code for the four cases summarized above in Table 2.

The meaning of output values (which include echoing of input) are not always clear, so a description of them is tabulated here. Table 4 has the input variables while Table 5 has the output variables. The listings of sample output (following the tables) may be consulted for more details.

VARIABLE	SAMPLE VALUE	MEANING
ALFNU1,2	EBTI KT8	identification label
IMX	181	no. of increments in r
XMAX	45.0	distance from center of cavity to radial boundary in cm
KMXM1	41	no. of increments in z
YMAX	22.225006	Separation of coil plane and midplane in cm
IBUG	0	code for extra debugging output
KMX	42	KMXM1 + 1
LMX	7602	IMX*KMX
SEP	44.5	separation between coils in cm
RADIUS ...	9.525	radius of mirror coil (average) cm (single loop approximation used)
NP	4	no. pairs of mirror coils used to approximate infinite set
NOM	5	no. pairs of rings used to calculate boundary values
ITERMX	20	no. of iterations over outer loop.
INMX	25	initial no. of iterations for inner loop
IDOUB	5	double INMX when ITER a multiple of IDOUB
KCUT	38	don't calculate vacuum field when this close to coil (K < KCUT or I < ICUT required)
ICUT	36	don't calculate vac.field when this close to coil
ORC	1.9	acceleration parameter for SOR

Table 4. Explanation of values that must be input to EQUIL code.

VARIABLE	SAMPLE VALUE	MEANING
ITNSC	0	zero for tensor pressure only
SLOP	1.	mixing parameter for outer loop
INPUT	1	one for pressure model chosen
RSI1,2,3,4	11,13,13,15	radial limits in midplane for pressure function
BC	0.60	normalized cutoff field for pres. mode
S	0.20	coef. in pressure model
IMNDL	20	begin output for this I
IMXDL	80	end output for this I
IMDEL	2	increment for I on output
IBC	1	one for regular boundary cond.
RMSC	8.0	value used by multipole expansion
JCUT	10	no. terms in multipole expansion used to set boundary cond.

Table 4. (continued)

VARIABLE	SAMPLE VALUE	MEANING
ITER	10	outer loop iteration no.
N	25	inner loop iteration no.
RES	0.17E-2	residual for SOR at ITER, N
RMID	0.475E+01	radius in midplane in cm
CURD	-0.599E-04	current density at RMID
MODB	0.916E+00	normalized B field at RMID
P-PERP	0.0	perpendicular pressure (normalized)
P-PARA	0.0	parallel pressure (normalized)
DLOB	0.0	not calculated by this version
SI	-0.142E-02	diamagnetic flux value (normalized)
SIV	0.108E+02	vacuum flux coordinate
WPER	0.80354E+00	perpendicular energy (normalized)
WPAR	0.48644E-01	parallel energy (normalized)
RAD	4.75	radius for pressure map (cm)
Z	.56	axial coord. for pres. map (cm)
pressure map follows		
RS	2.8000E+01	pickup coil radius (cm)
ZS	9.5	pickup coil axial position (cm from midplane)
SI	-9.5891E+02	diamagnetic flux linked by pickup coil (normalized)
SIV	1.4291E+02	vacuum flux linked
STP	1.4282E+02	SI + SIV

Table 5. Explanation of calculated values output by EQUIL code.

```

CKHC        VERSION WITH MAXIMUM ARRAY DIMENSIONS. REQUIRES 1M TO LOAD.      EQU00
CKHC        VERSION WITHOUT PHI,PHIR,VR,VZ,RMID USE; HENCE NO DLOB CALC.      EQU00
CKHC        20JAN81 CORRECT INCORRECT OUTPUT OF SOME ZEROS IN P MAP.      EQU00
CKHC        13JAN81 ADD DOUBLING OF ITERATIONS OF DESI AT ITER = MULTIPLES      EQU00
CKHC        OF IDOUB. ADD STOP IN DESI WHEN RES.GT.100 AND IBUG=0.      EQU00
CKHC        10JAN81 ADD INPUT OF IMDEL; CHANGE OUTPUT OF WPER MAP.      EQU00
CKHC        05JAN81 CORRECT PLACEMENT OF LL & II INSIDE LOOP IN CALB.      EQU00
CKHC        03JAN81 INSERT SECTION IN BATS TO CALCULATE WPER, OUTPUT P MAP      EQU00
CKHC        AND PSI VALUES; OTHER CHANGES AT CK COMMENT LINES.      EQU00
CKHC        22DEC80 CHANGE READS TO 5 WRITES TO 6 TO ALLOW OVER 80 CHAR LINES EQU00
CKHC        18DEC80 THIS VERSION RESTORES LINES KRIS HAD COMMENTED OUT      EQU00
CKHC        18DEC80 CHANGE READ UNIT FROM 50 TO 7, WRITE UNIT FROM 51 TO 8.      EQU00
C        PROGRAM EQUIL(DATA,TAPE50=DATA,OUTPUT,TAPE51=OUTPUT,      EQU00
C        *                    EULER,TAPE52=EULER)      EQU00
C      EQU00
C        MAIN PROG AXIALLY SYMMETRIC EQUILIBRIA      EQU00
C      EQU00
COMMON/DEX/ IMX,KMX,IMXM1,KMXM1,LMX,KFLG,KCUT,ICUT,ITERMX,INMX      EQU00
COMMON/GEO/ XMAX,XMIN,DELX,YMAX,YMIN,DELY,SEP,RADL      EQU00
COMMON/SCALE/ SC1(250),SC2,SC3,SC4,SC5,SC6(250),SC7,SC8,SC9(250),      EQU00
* SC10(250),SC12(250),SC13      EQU00
COMMON/BCAL/ IMIN1(250),IMAX1(250)      EQU00
COMMON/PCAL/ SI0,BA,BA2,BC,SIMN,SIMX,BETA      EQU00
COMMON/NPCA/ ICALP,ISICR      EQU00
COMMON/ADE/ ORC      EQU00
COMMON/MODGR/ KNXGR,IMNGR,IMXGR      EQU00
COMMON/BCDEX/ IBC,JCUT      EQU00
COMMON/RETI/ ITER      EQU00
COMMON/NUALF/ ALFNU1,ALFNU2      EQU00
COMMON/PRSTP/ ITNSC      EQU00
COMMON/PAIRS/ NP,NPM      EQU00
COMMON/ADAUX/ IMXTP,IMNTP,IMDEL      EQU00
COMMON/BUG/ IBUG      EQU00
DIMENSION SI(12000),SIV(12000),STP(12000),SIGMA(12000),CO1(12000),      EQU00
* CO2(12000),DTRM(12000),CTRM(12000),B(12000),      EQU00
*                    PHI(1),PHIR(1)      EQU00
DIMENSION VR(1),VZ(1),      EQU00
* RMID(1)      EQU00
1000 FORMAT(1H ,2(I4,2X,F14.6,2X),I4)      EQU00
1001 FORMAT(1H ,6HIMX = ,I4,2X,7HXMAX = ,F14.6/      EQU00
* 1H ,8HKMXM1 = ,I4,2X,7HYMAX = ,F14.6/      EQU00
* 1H ,7HIBUG = ,I4,5X,33HIBUG OF ZERO GIVES MIN DIAG PRINT)      EQU00
1002 FORMAT(1H ,4(F14.6,2X))      EQU00
1003 FORMAT(1H ,13HINPUT BETA = ,F14.6,2X,11HCUTOFF B = ,F14.6/      EQU00
* 1H ,9HMIN SI = ,F14.6,2X,9HMAX SI = ,F14.6)      EQU00
1004 FORMAT(1H ,2(F14.6,2X),2(I4,2X))      EQU00
1005 FORMAT(1H ,6HSEP = ,F14.6,2X,17HRADIUS OF LOOP = ,F14.6/      EQU00
* 1H ,20HNO COIL PAIRS NP = ,I4/      EQU00
* 1H ,37HNO PLASMA PAIRS FOR MULTIPOLE NPM = ,I4)      EQU00
1006 FORMAT(1H ,5(I4,2X),F14.6)      EQU00
1007 FORMAT(1H ,39HMAX NO OF OVERALL ITERATIONS ITERMX = ,I4/      EQU00
* 1H ,37HMAX NO OF ITERATIONS FOR DE INMX = ,I4/      EQU00
* 1H ,40HDOUBLE INMX WHEN ITER A MULT. OF IDOUB= ,I4/      EQU00
* 1H ,50HTO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION/      EQU00
* 1H ,45HIT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT/      EQU00

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      * 1H ,7HKCUT = ,I4,5X,7HICUT = ,I4/1H ,6HORC = ,F14.6//)      EQU00
1008 FORMAT(1H ,7HSIMN = ,E14.6,5X,7HSIMX = ,E14.6,5X,7HKFLG = ,I6)      EQU00
1009 FORMAT(1H ,4HK = ,I4,1X,8HIMIN1 = ,I6,1X,8HIMAX1 = ,I6)      EQU00
1010 FORMAT(1H ,7HITER = ,I4,5X,14HB AT ORIGIN = ,E14.6)      EQU00
1100 FORMAT(2A4)      EQU00
1101 FORMAT(1H1/1H ,2A4)      EQU00
1200 FORMAT(1H ,17HNOTE THAT    KMX = ,I5,5X,6HLMX = ,I5)      EQU00
C      EQU00
C    INPUT:      EQU00
C      EQU00
C    ALPNU1,ALFNU2 - ALPHA-NUMERIC LABEL (TOTAL OF 8 CHARACTERS)      EQU00
C    IMX            - NUMBER OF GRID POINTS FROM THE AXIS TO XMAX      EQU00
C    XMAX           - GRID DISTANCE RADially OUT FROM THE AXIS      EQU00
C    KMXM1          - NUMBER OF GRID POINTS MINUS 1 ALONG THE AXIS      EQU00
C                    (Z DIRECTION, FROM MID-PLANE TO COIL PLANE)      EQU00
C    YMAX           - GRID DISTANCE FROM THE MID-PLANE TOWARD THE COIL PLANE      EQU00
C    IBUG           - CAUSES DEBUGGING OUTPUT IN MAIN AND SUBROUTINE DESI      EQU00
C                    WHEN NON-ZERO      EQU00
C    SEP            - DISTANCE BETWEEN LOOPS      EQU00
C    RADL           - RADIUS OF LOOP      EQU00
C    NP             - NUMBER PAIRS USED TO CALCULATE PSI(VACCU)MM)      EQU00
C                    IN SUBROUTINE VACSI      EQU00
C    NPM            - NUMBER OF PAIRS USED TO CALCULATE GR IN      EQU00
C                    SUBROUTINE FCMULT      EQU00
C    ITERMX          - TOTAL NUMBER OF OVER ALL CODE ITERATIONS      EQU00
C    INMX           - NUMBER OF SUCCESSIVE OVER-RELAXATION ITERATIONS IN      EQU00
C                    SUBROUTINE DESI      EQU00
C    KCUT           - LIMIT IN Z DIRECTION TO AVOID CALCULATION OVER      EQU00
C                    SINGULARITY, IN SUBROUTINES JDISP AND VACSI      EQU00
C    ICUT           - LIMIT IN RADIAL DIRECTION TO AVOID CALCULATION OVER      EQU00
C                    SINGULARITY, IN SUBROUTINES JDISP AND VACSI      EQU00
C    ORC            - SCALES RESULT OF SOR IN SUBROUTINE DESI      EQU00
C      EQU00
C    SEE SUBROUTINES CALP, FCMULT, AND JDISP FOR OTHER INPUT INFORMATION.      EQU00
C      EQU00
C      CALL CHANGE(8H+EQUILGO)      EQU00
50    ISTART=0      EQU00
100    READ(5,1100,END=102)    ALFNU1,ALFNU2      EQU00
C      IF (EOF,50) 102,104      EQU00
C          GO TO 104      EQU00
102    CALL EXIT      EQU00
104    WRITE(6,1101) ALFNU1,ALFNU2      EQU00
      READ(5,1000)    IMX,XMAX,KMXM1,YMAX,IBUG      EQU00
      WRITE(6,1001) IMX,XMAX,KMXM1,YMAX,IBUG      EQU00
      IMXM1=IMX-1      EQU01
      DELX=XMAX/FLOAT(IMXM1)      EQU01
      XMIN=0.      EQU01
      KMX=KMXM1+1      EQU01
      LMX=IMX*KMX      EQU01
      DELY=YMAX/FLOAT(KMXM1-1)      EQU01
      WRITE(6,1200) KMX,LMX      EQU01
      YMIN=0.      EQU01
      KMXGR=KMXM1      EQU01
      IMXGR=IMXM1      EQU01
      IMNGR=1      EQU01

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      READ(5,1004)  SEP,RADL,NP,NPM
      WRITE(6,1005) SEP,RADL,NP,NPM
      READ(5,1006)  ITERMX,INMX,IDOUB,KCUT,ICUT,ORC
      WRITE(6,1007) ITERMX,INMX,IDOUB,KCUT,ICUT,ORC
      ITER=0
      IF(ISTART .NE. 0) GO TO 120
      DO 115 L=1,LMX
      DTRM(L)=0.
      CTRM(L)=0.
      SIGMA(L)=1.
115  SI(L)=0.
C
C  CALCULATE SCALE FACTORS USED IN ???
C
      CALL SCFAC
C
C  CALCULATE VACUUM PSI PRODUCED BY COILS
C
      CALL VACSI (SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B)
      ISTART=1
120  ICALP=0
      ISICR=0
C
C  READ PRESSURE DATA
C
      CALL CALP(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,
* RMID)
      IJDSP=0
C
C  READ FIELD INTEGRAL STUFF, SET WEIGHTS
C
      CALL JDISP(SI,SIV,STP,CO1,CO2,B,PHI,PHIR,VR,VZ,RMID,IJDSP,
* IJDSP1)
C
C  CALCULATE MULTIPOLE EXPANSION
C
      CALL FCMULT
C
C  CALCULATE B, CALLS CALP TO CALCULATE PRESSURE
C
200  CALL CALB(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,
* RMID)
CK
CK  WRITE(6,7007)(CTRM(L),L=IMNTP,IMXTP)
7007  FORMAT(250(1X,1P10E12.3))
      IJDSP=1
      IJDSP1=0
C
C  PREPARE FOR FIELD LINE INTEGRALS (PSI=CONSTANT ON FIELD LINE)
C
      CALL JDISP(SI,SIV,STP,CO1,CO2,B,PHI,PHIR,VR,VZ,RMID,IJDSP,IJDSP1)
C
C  COMPUTE INTEGRAL DL OVER B FOR STABILITY CRITERION
C
      CALL BATS(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,

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      * RMID)
C
C DAVE NELSON'S PERSONAL STUFF, DONE ON FINAL ITERATION
C
CK   CALL DAVE(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,
CK   * RMID)
C
C DETERMINE DRIVING TERMS AND COEFFECIENTS FOR DEL*PSI, MULTIPOLE MOMENE
C
      CALL DTCOF (SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B)
      IF(IBC .EQ. 0) GO TO 201
C
C SET UP LATERAL BOUNDARY CONDITIONS BASED ON MULTIPOLE MOMENTS
C
      CALL SETBC (SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B)
201  WRITE(6,1010) ITER,B(1)
CK
CK   WRITE(6,7007)(DTRM(L),L=IMNTP,IMXTP)
C 201  CONTINUE
      IF(IBUG .EQ. 0) GO TO 211
      WRITE(6,1008) SIMN,SIMX,KFLG
      DO 210 K=1,KMXM1
      WRITE(6,1009) K,IMIN1(K),IMAX1(K)
210  CONTINUE
211  IF(ITER .GE. ITERMX) GO TO 500
      ITER =ITER+1
CK
      IF(MOD(ITER,IDOUB).EQ.0)INMX=INMX*2
C
C SOLVE DEL*PSI+GRAD(SIGMA)/SIGMA.GRAD(PSI(P))=-(R**2/SIGMA)...
C   FOR FIXED SIGMA AND P-PARALLEL
C
215  CALL DESI  (SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B)
      GO TO 200
500  CONTINUE
      IJDSP=1
      IJDSP1=1
C
C PREPARE FOR FINAL FIELD LINE INTEGRALS
C
      CALL JDISP(SI,SIV,STP,CO1,CO2,B,PHI,PHIR,VR,VZ,RMID,IJDSP,
      * IJDSP1)
      GO TO 100
      END
C
C***-----

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SUBROUTINE BATS(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,      BAT00
* VR,VZ,RMID)                                                    BAT00
C                                                                    BA100
C      COMPUTES DL OVER B AND ITS PSI DERIVATIVE AND INTEGRAL      BAT00
C      B DL AND INTEGRAL DL OVER B-CUBED                          BAT00
C      ALSO FORMS STABILITY CRITERIA BASED ON FIELD LINE INTEGRALS BAT00
C                                                                    BAT00
COMMON/DEX/ IMX,KMX,IMXM1,KMXM1,LMX,KFLG,KCUT,ICUT,ITERMX,INMX      BAT00
COMMON/SCALE/ SC1(250),SC2,SC3,SC4,SC5,SC6(250),SC7,SC8,SC9(250), BAT00
* SC10(250),SC12(250),SC13                                         BAT00
COMMON/GEO/ XMAX,XMIN,DELX,YMAX,YMIN,DELY,SEP,RADL                BAT00
COMMON/PCAL/ SIO,BA,BA2,BC,SIMN,SIMX,BETA                        BAT00
COMMON/PAVE/ AVEP,PSCL,PSCLP,PERP,PERPP,PARA,PARAP,CHAT,G0,GPO,  BAT00
* IOUT                                                             BAT00
COMMON/STAB/ DLOB(250),BDL(250),DLOB3(250),DLOBP(250),PSAVE(250), BAT00
* PPSAVE(250)                                                      BAT00
COMMON/ADAUX/ IMXTP,IMNTP,IMDEL                                  BAT00
COMMON/RETI/ITER                                                  BAT00
DIMENSION SI(1),SIV(1),STP(1),SIGMA(1),CO1(1),CO2(1),DTRM(1),   BAT00
* CTRM(1),B(1),PHI(1),PHIR(1),VR(1),VZ(1),RMID(1)               BAT00
DIMENSION WTS(7)                                                  BAT00
DATA WTS(1)/.3042245/,WTS(2)/1.460384/,WTS(3)/.45344640/        BAT00
DATA WTS(4)/1.471429/,WTS(5)/.7393932/,WTS(6)/1.082474/         BAT00
DATA WTS(7)/.9886326/                                             BAT00
C                                                                    BAT00
1002 FORMAT(1H ,7(E10.3,1X))                                       BAT00
1022 FORMAT(1H ,8(E10.3,1X))                                       BAT00
1003 FORMAT(1H ,2(5X,E14.6))                                       BAT00
1006 FORMAT(1H ,6(E14.6,1X))                                       BAT00
1000 FORMAT(/7X,4HRMID,7X,4HPSCL,6X,5HPSCLP,5X,6HP-PERP,5X,      BAT00
*          6HP-PARA,7X,4HDLOB)                                       BAT00
1020 FORMAT(/7X,4HRMID,7X,4HCURD,6X,5HMODB ,5X,6HP-PERP,5X,      BAT00
*          6HP-PARA,7X,4HDLOB,7X,4HSI ,7X,4HSIV )                   BAT00
1004 FORMAT(1H1/1H ,4X,6HRADIUS,5X,14HPPRIME+GAMMA*P,2X,         BAT00
* 13HUPRIME-PPRIME                                                  BAT00
* ,1X,14HUPRIME-PPRIME*,4X,11HGENERALIZED,3X,10HBALLOONING/      BAT00
* 1H ,15X,9H*UPRIME/U,8X,6HU**2/I,7X,15HDL OVER B-CUBED,4X,     BAT00
* 11HINTERCHANGE/)                                                 BAT00
C                                                                    BAT00
CK      SKIP DLOB CAL TO ELIMINATE USE OF PHI,PHIR,VR,VZ,RMID    BAT00
GO TO 150                                                         BAT00
C      CALC DLOB BDL DLOB3                                         BAT00
C                                                                    BAT00
CK
10      IF(ITER.LT.ITERMX)RETURN                                    BAT00
CK                                                                    BAT00
CK100DO 110 I=1,IMXTP                                              BAT00
DO 110 I=IMNTP,IMXTP                                              BAT00
DLOB(I)=0.                                                         BAT00
BDL(I)=0.                                                         BAT00
DLOB3(I)=0.                                                       BAT00
L=I-IMX                                                           BAT00
DO 110 K=1,KMXM1                                                  BAT00
L=L+IMX                                                           BAT00
DUM=CO2(L)                                                         BAT00

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IF(K .LE. 7) DUM=DUM*WTS(K)	BAT00
KTMP=KMX-K	BAT00
IF(K .GE. KMXM1-6) DUM=DUM*WTS(KTMP)	BAT00
DLOB(I)=DLOB(I)+DUM/CO1(L)	BAT00
BDL(I)=BDL(I)+CO1(L)*DUM	BAT00
DLOB3(I)=DLOB3(I)+DUM/(CO1(L)**3)	BAT00
110 CONTINUE	BAT00
C	BAT00
C CALC DLOBP OR U PRIME	BAT00
C	BAT00
120 DLOBP(1)=(16.*DLOB(2)-DLOB(3)-15.*DLOB(1))/6.	BAT00
DLOBP(2)=(DLOBP(1)+(DLOB(3)-4.*DLOB(2)+3.*DLOB(1))/3.)/CO1(2)	BAT00
DLOBP(1)=DLOBP(1)/CO1(1)	BAT00
IDUM=IMXTP-1	BAT00
CK	BAT00
ID2=IMNTP+2	BAT00
CK DO 122 I=3,IDUM	BAT00
DO 122 I=ID2,IDUM	BAT00
122 DLOBP(I)=(DLOB(I+1)-DLOB(I-1))/(2.*CO1(I)*FLOAT(I-1))	BAT00
DLOBP(IMXTP)=(DLOB(IMXTP)-DLOB(IMXTP-1))/(CO1(IMXTP)*FLOAT(IDUM))	BAT00
DUM=1./(DELX**2)	BAT00
DO 125 I=1,IMXTP	BAT00
125 DLOBP(I)=DUM*DLOBP(I)	BAT00
C	BAT00
C CALC P AND P-PRIME AND MAKE FIRST TABLE	BAT00
C	BAT00
150 IF (ITER .LT. ITERMX) RETURN	BAT00
200 IHOLD=IOUT	BAT00
IOUT=0	BAT00
IOUT=2	BAT00
WRITE(6,1020)	BAT00
CK WRITE(6,1000)	BAT00
CK DO 210 I=1,IMXTP	BAT00
DO 210 I=IMNTP,IMXTP	BAT00
SI0=STP(I)	BAT00
CK BA=CO1(I)	BAT00
BA=B(I)	BAT00
CALL CALP(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ,	BAT00
* RMID)	BAT00
PSAVE(I)=PSCL	BAT00
PPSAVE(I)=PSCLP	BAT00
PER=PERP-PSCL	BAT00
PAR=PARA-PSCL	BAT00
CJT=-0.5*SC13*SC12(I)*(SI(I+1)+SI(I-1)-2.*SI(I))+	BAT00
1 SC9(I)*SC12(1)*(SI(I+1)-SI(I-1))	BAT01
CK WRITE(6,1002) SC6(I),PSAVE(I),PPSAVE(I),PER,PAR,DLOB(I)	BAT01
WRITE(6,1022) SC6(I),CJT,BA,PER,PAR,DLOB(I),SI(I),SIV(I)	BAT01
210 CONTINUE	BAT01
CK SKIP SECOND TABLE	BAT01
GO TO 220	BAT01
C	BAT01
C MAKE SECOND TABLE	BAT01
C	BAT01
C WRITE(6,1004)	BAT01
CK DO 220 I=1,IMXTP	BAT01

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CK      DUM1=PPSAVE(I)+1.6666667*PSAVE(I)*DLOBP(I)/DLOB(I)      BAT01
CK      DUM2=DLOBP(I)-PPSAVE(I)*(DLOB(I)**2)/BDL(I)             BAT01
CK      DUM3=DLOBP(I)-PPSAVE(I)*DLOB3(I)                         BAT01
CK      DUM4=DUM1*DUM2                                           BAT01
CK      DUM5=DUM1*DUM3                                           BAT01
C       WRITE(6,1006) SC6(I),DUM1,DUM2,DUM3,DUM4,DUM5          BAT01
220     CONTINUE                                                 BAT01
CKHC                                         BAT01
CK      CALCULATE WPER, WPAR AND OUTPUT PLASMA PER P MAP:      BAT01
      WPER=0.                                                     BAT01
      WPAR=0.                                                     BAT01
      DVOL1=0.25/SC5                                             BAT01
      L1C=-IMX                                                    BAT01
      DO 360 K=1,KMX                                             BAT01
      L1C=L1C+IMX                                                 BAT01
      DO 350 I=1,IMX                                             BAT01
      IF((K.GE.KCUT).AND.(I.GE.ICUT))GO TO 350                  BAT01
      L=L1C+I                                                     BAT01
      BA=B(L)                                                     BAT01
CK      IF(BA.GE.BC)GO TO 350                                     BAT01
      IF(BA.LT.BC)GO TO 340                                       BAT01
      DTRM(L)=0.                                                  BAT01
      GO TO 350                                                    BAT01
340     SIO=STP(L)                                                BAT01
      CALL CALP(SI,SIV,STP,SIGMA,CO1,CO2,DTRM,CTRM,B,PHI,PHIR,VR,VZ, BAT01
      * RMID)                                                     BAT01
CK      NOTE USE OF PSAVE AND DTRM - NO LONGER AVAILABLE FOR DAVE. BAT01
      DTRM(L)=PERP                                                BAT01
      IF((PERP.EQ.0.).AND.(PARA.EQ.0.))GO TO 350                BAT01
      DVOL=DVOL1/SC9(I)                                          BAT01
      WPER=WPER+DVOL*PERP                                         BAT01
      WPAR=WPAR+DVOL*PARA                                         BAT01
350     CONTINUE                                                 BAT01
360     CONTINUE                                                 BAT01
      WPAR=0.5*WPAR                                              BAT01
      WRITE(6,3001)WPER,WPAR                                     BAT01
3001    FORMAT(/6H WPER= ,E14.5,8H    WPAR= ,E14.5/)            BAT01
CK      OUTPUT MAP OF WPER                                       BAT01
      WRITE(6,3002)                                              BAT01
3002    FORMAT(1H1/27H RAD      P-PER: MID TO COIL    )        BAT01
      MSTEP=KMXM1/21                                             BAT01
      IF(MSTEP.LT..1)MSTEP=1                                     BAT01
      MAXST=21*MSTEP                                             BAT01
      IF(KMXM1.LT.21)MAXST=KMXM1                                BAT01
      WRITE(6,3102)(SC1(K),K=1,MAXST,MSTEP)                     BAT01
3102    FORMAT(/6H    Z = ,21F6.2/)                             BAT01
      DO 370 I = IMNTP,IMXTP,IMDEL                              BAT01
      DO 365 K=1,MAXST,MSTEP                                     BAT01
365     PSAVE(K)=DTRM((K-1)*IMX+I)                              BAT01
      WRITE(6,3003)SC6(I),(PSAVE(K),K=1,MAXST,MSTEP)           BAT01
3003    FORMAT(1X,F5.2,21F6.3)                                  BAT01
370     CONTINUE                                                 BAT01
CK      OUTPUT SI AT SPECIFIED LOCATIONS                        BAT01
      WRITE(6,3004)                                              BAT01
3004    FORMAT(8X,2HRS,14X,2HZS,14X,2HSI,14X,3HSIV,13X,3HSTP ) BAT01

```

380	READ(5,3005,END=500)RS,ZS	BAT01
3005	FORMAT(2G8.4)	BAT01
	I=1+RS/DELX	BAT01
	K=1+ZS/DELY	BAT01
	L=I+(K-1)*IMX	BAT01
	WRITE(6,3006)RS,ZS,SI(L),SIV(L),STP(L)	BAT01
3006	FORMAT(1P5E16.4)	BAT01
	GO TO 380	BAT01
500	STOP	BAT01
CKHC		BAT01
CK	IOUT=IHOLD	BAT01
CK	RETURN	BAT01
	END	BAT01
C		BAT01

1

```

EBTI KT8
IMX = 181 XMAX = 45.000000
KMXM1 = 41 YMAX = 22.225006
IRUG = 0 IRUG OF ZERO GIVES MIN DIAG PRINT
NOTE THAT KMX = 42 LMX = 7602
SEP = 44.449997 RADIUS OF LOOP = 9.525000
NO COIL PAIRS NP = 4
NO PLASMA PAIRS FOR MULTIPOLE NPM = 5
MAX NO OF OVERALL ITERATIONS ITERMX = 20
MAX NO OF ITERATIONS FOR DE INMX = 25
DOUBLE INMX WHEN ITER A MULT. OF IDOUB= 5
TO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION
IT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT
K CUT = 38 ICUT = 36
ORC = 1.900000

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DATA FOR CALP
ITNSC = 0 SLOP = 1.000000
INPUT = 1
RADII FOR SI DEP OF TENSOR PART
RSI1 = 11.00 RSI2 = 13.00 RSI3 = 13.00 RSI4 = 15.00
BC = 0.60
SINCE INPUT EQUALS ONE WE HAVE THE TAU CONST CASE
S = 0.200000
CONSTANTS FOR JDISP
IMNDL = 20 INXDL = 80 IMDEL = 2
IBC = 1
RMSC = 8.000000
JCUT = 10
IF IBC IS ZERO FLUX CONSERVING BC ARE USED
RMSC IS USED FOR THE MULTIPOLE EXPANSION
JCUT IS THE NUMBER OF TERMS IN THE MULTIPOLE EXPANSION

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(Output from EQUIL for 2% "beta" case)
(on this and next 3 pages)

```

ITER = 0      B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.167818E-01
N = 25 RES = 0.512126E-02
ITER = 1      B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.948173E-02
N = 25 RES = 0.321801E-02
ITER = 2      B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.631712E-02
N = 25 RES = 0.241754E-02
ITER = 3      B AT ORIGIN = 0.100009E+01
N = 1 RES = 0.360836E-02
N = 25 RES = 0.178328E-02
ITER = 4      B AT ORIGIN = 0.100008E+01
N = 1 RES = 0.212197E-02
N = 50 RES = 0.638005E-03
ITER = 5      B AT ORIGIN = 0.100006E+01
N = 1 RES = 0.110653E-02
N = 50 RES = 0.428791E-03
ITER = 6      B AT ORIGIN = 0.100008E+01
N = 1 RES = 0.656961E-03
N = 50 RES = 0.317713E-03
ITER = 7      B AT ORIGIN = 0.100009E+01
N = 1 RES = 0.395834E-03
N = 50 RES = 0.242864E-03
ITER = 8      B AT ORIGIN = 0.100010E+01
N = 1 RES = 0.243099E-03
N = 50 RES = 0.190866E-03
ITER = 9      B AT ORIGIN = 0.100011E+01
N = 1 RES = 0.189859E-03
N = 100 RES = 0.122536E-03
ITER = 10     B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.122095E-03
N = 100 RES = 0.840853E-04
ITER = 11     B AT ORIGIN = 0.100013E+01
N = 1 RES = 0.837450E-04
N = 100 RES = 0.582655E-04
ITER = 12     B AT ORIGIN = 0.100014E+01
N = 1 RES = 0.580286E-04
N = 100 RES = 0.405851E-04
ITER = 13     B AT ORIGIN = 0.100014E+01
N = 1 RES = 0.404433E-04
N = 100 RES = 0.282933E-04
ITER = 14     B AT ORIGIN = 0.100014E+01
N = 1 RES = 0.281512E-04
N = 200 RES = 0.135819E-04
ITER = 15     B AT ORIGIN = 0.100015E+01
N = 1 RES = 0.181005E-04
N = 200 RES = 0.661921E-05
ITER = 16     B AT ORIGIN = 0.100015E+01
N = 1 RES = 0.129368E-04
N = 200 RES = 0.327134E-05
ITER = 17     B AT ORIGIN = 0.100015E+01
N = 1 RES = 0.841391E-05
N = 200 RES = 0.172169E-05
ITER = 18     B AT ORIGIN = 0.100015E+01
N = 1 RES = 0.547791E-05
N = 200 RES = 0.899626E-06
ITER = 19     B AT ORIGIN = 0.100015E+01
N = 1 RES = 0.341564E-05
N = 400 RES = 0.317566E-06

```

RMID	CURD	MODB	P-PERP	P-PARA	ML0B	SI	SIV
0.475E+01	-0.599E-04	0.916E+00	0.0	0.0	0.0	-0.142E-02	0.108E+02
0.500E+01	-0.660E-04	0.907E+00	0.0	0.0	0.0	-0.149E-02	0.119E+02
0.525E+01	-0.730E-04	0.898E+00	0.0	0.0	0.0	-0.154E-02	0.131E+02
0.550E+01	-0.804E-04	0.888E+00	0.0	0.0	0.0	-0.157E-02	0.143E+02
0.575E+01	-0.890E-04	0.878E+00	0.0	0.0	0.0	-0.158E-02	0.155E+02
0.600E+01	-0.983E-04	0.869E+00	0.0	0.0	0.0	-0.155E-02	0.168E+02
0.625E+01	-0.109E-03	0.858E+00	0.0	0.0	0.0	-0.148E-02	0.181E+02
0.650E+01	-0.121E-03	0.848E+00	0.0	0.0	0.0	-0.137E-02	0.195E+02
0.675E+01	-0.134E-03	0.837E+00	0.0	0.0	0.0	-0.120E-02	0.209E+02
0.700E+01	-0.149E-03	0.826E+00	0.0	0.0	0.0	-0.963E-03	0.223E+02
0.725E+01	-0.166E-03	0.815E+00	0.0	0.0	0.0	-0.655E-03	0.238E+02
0.750E+01	-0.185E-03	0.803E+00	0.0	0.0	0.0	-0.260E-03	0.252E+02
0.775E+01	-0.207E-03	0.791E+00	0.0	0.0	0.0	0.237E-03	0.268E+02
0.800E+01	-0.231E-03	0.779E+00	0.0	0.0	0.0	0.852E-03	0.283E+02
0.825E+01	-0.260E-03	0.767E+00	0.0	0.0	0.0	0.160E-02	0.299E+02
0.850E+01	-0.292E-03	0.755E+00	0.0	0.0	0.0	0.251E-02	0.315E+02
0.875E+01	-0.329E-03	0.742E+00	0.0	0.0	0.0	0.361E-02	0.331E+02
0.900E+01	-0.371E-03	0.730E+00	0.0	0.0	0.0	0.492E-02	0.347E+02
0.925E+01	-0.420E-03	0.718E+00	0.0	0.0	0.0	0.648E-02	0.364E+02
0.950E+01	-0.476E-03	0.705E+00	0.0	0.0	0.0	0.832E-02	0.380E+02
0.975E+01	-0.540E-03	0.692E+00	0.0	0.0	0.0	0.105E-01	0.397E+02
0.100E+02	-0.614E-03	0.679E+00	0.0	0.0	0.0	0.131E-01	0.414E+02
0.103E+02	-0.700E-03	0.667E+00	0.0	0.0	0.0	0.161E-01	0.431E+02
0.105E+02	-0.798E-03	0.654E+00	0.0	0.0	0.0	0.197E-01	0.448E+02
0.108E+02	-0.910E-03	0.641E+00	0.0	0.0	0.0	0.238E-01	0.465E+02
0.110E+02	-0.104E-02	0.629E+00	0.0	0.0	0.0	0.287E-01	0.483E+02
0.113E+02	-0.118E-02	0.616E+00	0.0	0.0	0.0	0.344E-01	0.500E+02
0.115E+02	0.335E-03	0.603E+00	0.0	0.0	0.0	0.411E-01	0.517E+02
0.118E+02	0.453E-02	0.589E+00	0.487E-03	0.443E-05	0.0	0.477E-01	0.534E+02
0.120E+02	0.951E-02	0.574E+00	0.171E-02	0.371E-04	0.0	0.511E-01	0.552E+02
0.123E+02	0.137E-01	0.559E+00	0.354E-02	0.125E-03	0.0	0.473E-01	0.569E+02
0.125E+02	0.169E-01	0.543E+00	0.579E-02	0.291E-03	0.0	0.328E-01	0.586E+02
0.128E+02	0.163E-01	0.524E+00	0.825E-02	0.555E-03	0.0	0.478E-02	0.603E+02
0.130E+02	0.115E-01	0.509E+00	0.101E-01	0.832E-03	0.0	-0.370E-01	0.620E+02
0.133E+02	0.520E-02	0.495E+00	0.111E-01	0.106E-02	0.0	-0.890E-01	0.637E+02
0.135E+02	-0.228E-02	0.482E+00	0.112E-01	0.122E-02	0.0	-0.146E+00	0.654E+02
0.138E+02	-0.108E-01	0.471E+00	0.102E-01	0.123E-02	0.0	-0.203E+00	0.671E+02
0.140E+02	-0.175E-01	0.462E+00	0.821E-02	0.106E-02	0.0	-0.251E+00	0.687E+02
0.143E+02	-0.205E-01	0.455E+00	0.566E-02	0.775E-03	0.0	-0.284E+00	0.704E+02
0.145E+02	-0.189E-01	0.449E+00	0.303E-02	0.435E-03	0.0	-0.300E+00	0.720E+02
0.148E+02	-0.115E-01	0.441E+00	0.901E-03	0.157E-03	0.0	-0.299E+00	0.737E+02
0.150E+02	-0.100E-02	0.430E+00	0.0	0.0	0.0	-0.287E+00	0.753E+02
0.153E+02	0.177E-02	0.419E+00	0.0	0.0	0.0	-0.274E+00	0.769E+02
0.155E+02	0.140E-02	0.407E+00	0.0	0.0	0.0	-0.262E+00	0.785E+02
0.158E+02	0.116E-02	0.396E+00	0.0	0.0	0.0	-0.251E+00	0.800E+02
0.160E+02	0.987E-03	0.385E+00	0.0	0.0	0.0	-0.242E+00	0.816E+02
0.163E+02	0.851E-03	0.374E+00	0.0	0.0	0.0	-0.233E+00	0.831E+02
0.165E+02	0.742E-03	0.364E+00	0.0	0.0	0.0	-0.225E+00	0.846E+02
0.168E+02	0.650E-03	0.353E+00	0.0	0.0	0.0	-0.218E+00	0.861E+02
0.170E+02	0.573E-03	0.343E+00	0.0	0.0	0.0	-0.211E+00	0.875E+02
0.173E+02	0.507E-03	0.332E+00	0.0	0.0	0.0	-0.205E+00	0.890E+02
0.175E+02	0.451E-03	0.322E+00	0.0	0.0	0.0	-0.199E+00	0.904E+02
0.178E+02	0.402E-03	0.313E+00	0.0	0.0	0.0	-0.194E+00	0.918E+02
0.180E+02	0.360E-03	0.303E+00	0.0	0.0	0.0	-0.189E+00	0.931E+02
0.183E+02	0.322E-03	0.294E+00	0.0	0.0	0.0	-0.184E+00	0.945E+02
0.185E+02	0.290E-03	0.285E+00	0.0	0.0	0.0	-0.180E+00	0.958E+02
0.188E+02	0.261E-03	0.277E+00	0.0	0.0	0.0	-0.176E+00	0.971E+02
0.190E+02	0.236E-03	0.268E+00	0.0	0.0	0.0	-0.172E+00	0.984E+02
0.193E+02	0.214E-03	0.259E+00	0.0	0.0	0.0	-0.169E+00	0.997E+02
0.195E+02	0.195E-03	0.251E+00	0.0	0.0	0.0	-0.165E+00	0.101E+03
0.198E+02	0.177E-03	0.243E+00	0.0	0.0	0.0	-0.162E+00	0.102E+03

(Pressure Map)

1

RAD P-2ER: MID TO COIL

Z = 0.0 0.56 1.11 1.67 2.22 2.78 3.33 3.89 4.45 5.00 5.56 6.11 6.67 7.22 7.78 8.33 8.89 9.45 10.00 10.56 11.

85	4.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	6.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	6.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	9.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	9.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11.75	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12.25	0.004	0.004	0.003	0.003	0.002	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12.75	0.008	0.008	0.008	0.007	0.006	0.005	0.003	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	13.25	0.011	0.011	0.010	0.010	0.008	0.007	0.005	0.003	0.001	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	13.75	0.010	0.010	0.009	0.008	0.006	0.005	0.003	0.001	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	14.25	0.006	0.005	0.005	0.004	0.002	0.001	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	14.75	0.001	0.001	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	15.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	15.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	16.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	16.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	17.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	17.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	18.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	18.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	19.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	19.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RS		ZS				SI				SIV				STP							
2.8000E+01		9.5000E+00				-9.5891E-02				1.4291E+02				1.4282E+02							

R; T=802.58/812.35 11:50:37

1

EBTI KT8

IMX = 181 XMAX = 45.000000
 KMXM1 = 41 YMAX = 22.225006
 IBUG = 0 IBUG OF ZERO GIVES MIN DIAG PRINT
 NOTE THAT KMX = 42 LMX = 7602
 SEP = 44.449997 RADIUS OF LOOP = 9.525000
 NO COIL PAIRS NP = 4
 NO PLASMA PAIRS FOR MULTIPOLE NPM = 5
 MAX NO OF OVERALL ITERATIONS ITERMX = 20
 MAX NO OF ITERATIONS FOR IE INMX = 25
 DOUBLE INMX WHEN ITER A MULT. OF IDOUB= 5
 TO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION
 IT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT
 KCUT = 38 ICUT = 36
 ORC = 1.900000

DATA FOR CALP

ITNSC = 0 SLOP = 1.000000
 INPUT = 1
 RADII FOR SI DEP OF TENSOR PART
 RSI1 = 11.00 RSI2 = 12.00 RSI3 = 14.00 RSI4 = 15.00
 BC = 0.75
 SINCE INPUT EQUALS ONE WE HAVE THE TAU CONST CASE
 S = 0.200000
 CONSTANTS FOR JDISP
 IMNDL = 20 IMXDL = 80 IMDEL = 2
 IRC = 1
 RMSC = 8.000000
 JCUT = 10
 IF IRC IS ZERO FLUX CONSERVING BC ARE USED
 RMSC IS USED FOR THE MULTIPOLE EXPANSION
 JCUT IS THE NUMBER OF TERMS IN THE MULTIPOLE EXPANSION

(Output from EQUIL for 8% "beta" case)

```

ITER = 0      B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.110719E+00
N = 25 RES = 0.337880E-01
ITER = 1      B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.646567E-01
N = 25 RES = 0.218734E-01
ITER = 2      B AT ORIGIN = 0.999994E+00
N = 1 RES = 0.454155E-01
N = 25 RES = 0.169182E-01
ITER = 3      B AT ORIGIN = 0.999836E+00
N = 1 RES = 0.274437E-01
N = 25 RES = 0.115533E-01
ITER = 4      B AT ORIGIN = 0.999739E+00
N = 1 RES = 0.171078E-01
N = 50 RES = 0.422405E-02
ITER = 5      B AT ORIGIN = 0.999573E+00
N = 1 RES = 0.102930E-01
N = 50 RES = 0.283454E-02
ITER = 6      B AT ORIGIN = 0.999766E+00
N = 1 RES = 0.676787E-02
N = 50 RES = 0.219039E-02
ITER = 7      B AT ORIGIN = 0.999884E+00
N = 1 RES = 0.217318E-02
N = 50 RES = 0.173019E-02
ITER = 8      B AT ORIGIN = 0.999966E+00
N = 1 RES = 0.311370E-02
N = 50 RES = 0.135644E-02
ITER = 9      B AT ORIGIN = 0.100002E+01
N = 1 RES = 0.212428E-02
N = 100 RES = 0.893424E-03
ITER = 10     B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.167390E-02
N = 100 RES = 0.621322E-03
ITER = 11     B AT ORIGIN = 0.100018E+01
N = 1 RES = 0.129173E-02
N = 100 RES = 0.438386E-03
ITER = 12     B AT ORIGIN = 0.100022E+01
N = 1 RES = 0.973638E-03
N = 100 RES = 0.311862E-03
ITER = 13     B AT ORIGIN = 0.100025E+01
N = 1 RES = 0.722693E-03
N = 100 RES = 0.220827E-03
ITER = 14     B AT ORIGIN = 0.100027E+01
N = 1 RES = 0.530768E-03
N = 200 RES = 0.107683E-03
ITER = 15     B AT ORIGIN = 0.100030E+01
N = 1 RES = 0.430695E-03
N = 200 RES = 0.550411E-04
ITER = 16     B AT ORIGIN = 0.100031E+01
N = 1 RES = 0.321586E-03
N = 200 RES = 0.293434E-04
ITER = 17     B AT ORIGIN = 0.100032E+01
N = 1 RES = 0.221352E-03
N = 200 RES = 0.162069E-04
ITER = 18     B AT ORIGIN = 0.100032E+01
N = 1 RES = 0.147608E-03
N = 200 RES = 0.967245E-05
ITER = 19     B AT ORIGIN = 0.100032E+01
N = 1 RES = 0.959320E-04
N = 400 RES = 0.440669E-05

```

RNID	CURD	MODB	P-PERP	P-PARA	ILOB	SI	SIV
0.475E+01	-0.387E-03	0.915E+00	0.0	0.0	0.0	-0.106E-01	0.108E+02
0.500E+01	-0.421E-03	0.906E+00	0.0	0.0	0.0	-0.112E-01	0.119E+02
0.525E+01	-0.459E-03	0.897E+00	0.0	0.0	0.0	-0.117E-01	0.131E+02
0.550E+01	-0.499E-03	0.887E+00	0.0	0.0	0.0	-0.121E-01	0.143E+02
0.575E+01	-0.544E-03	0.878E+00	0.0	0.0	0.0	-0.123E-01	0.155E+02
0.600E+01	-0.590E-03	0.869E+00	0.0	0.0	0.0	-0.123E-01	0.168E+02
0.625E+01	-0.644E-03	0.858E+00	0.0	0.0	0.0	-0.121E-01	0.181E+02
0.650E+01	-0.696E-03	0.848E+00	0.0	0.0	0.0	-0.116E-01	0.195E+02
0.675E+01	-0.759E-03	0.837E+00	0.0	0.0	0.0	-0.108E-01	0.209E+02
0.700E+01	-0.822E-03	0.826E+00	0.0	0.0	0.0	-0.964E-02	0.223E+02
0.725E+01	-0.893E-03	0.815E+00	0.0	0.0	0.0	-0.808E-02	0.238E+02
0.750E+01	-0.966E-03	0.804E+00	0.0	0.0	0.0	-0.606E-02	0.252E+02
0.775E+01	-0.105E-02	0.792E+00	0.0	0.0	0.0	-0.351E-02	0.268E+02
0.800E+01	-0.114E-02	0.781E+00	0.0	0.0	0.0	-0.356E-03	0.283E+02
0.825E+01	-0.123E-02	0.769E+00	0.0	0.0	0.0	0.347E-02	0.299E+02
0.850E+01	-0.133E-02	0.757E+00	0.0	0.0	0.0	0.807E-02	0.315E+02
0.875E+01	-0.144E-02	0.745E+00	0.0	0.0	0.0	0.135E-01	0.331E+02
0.900E+01	-0.155E-02	0.733E+00	0.0	0.0	0.0	0.199E-01	0.347E+02
0.925E+01	-0.168E-02	0.721E+00	0.0	0.0	0.0	0.274E-01	0.364E+02
0.950E+01	-0.181E-02	0.708E+00	0.0	0.0	0.0	0.361E-01	0.380E+02
0.975E+01	-0.195E-02	0.696E+00	0.0	0.0	0.0	0.460E-01	0.397E+02
0.100E+02	-0.209E-02	0.683E+00	0.0	0.0	0.0	0.575E-01	0.414E+02
0.103E+02	-0.225E-02	0.671E+00	0.0	0.0	0.0	0.706E-01	0.431E+02
0.105E+02	-0.239E-02	0.659E+00	0.0	0.0	0.0	0.854E-01	0.448E+02
0.108E+02	-0.255E-02	0.646E+00	0.0	0.0	0.0	0.102E+00	0.465E+02
0.110E+02	0.867E-02	0.632E+00	0.0	0.0	0.0	0.121E+00	0.483E+02
0.113E+02	0.398E-01	0.613E+00	0.375E-02	0.376E-03	0.0	0.134E+00	0.500E+02
0.115E+02	0.600E-01	0.588E+00	0.126E-01	0.153E-02	0.0	0.120E+00	0.517E+02
0.118E+02	0.493E-01	0.561E+00	0.220E-01	0.316E-02	0.0	0.611E-01	0.534E+02
0.120E+02	0.226E-01	0.539E+00	0.272E-01	0.444E-02	0.0	-0.354E-01	0.552E+02
0.123E+02	0.128E-01	0.522E+00	0.290E-01	0.518E-02	0.0	-0.151E+00	0.569E+02
0.125E+02	0.139E-01	0.506E+00	0.306E-01	0.594E-02	0.0	-0.279E+00	0.586E+02
0.128E+02	0.145E-01	0.489E+00	0.324E-01	0.683E-02	0.0	-0.421E+00	0.603E+02
0.130E+02	0.138E-01	0.473E+00	0.339E-01	0.767E-02	0.0	-0.577E+00	0.620E+02
0.133E+02	0.151E-01	0.458E+00	0.353E-01	0.852E-02	0.0	-0.747E+00	0.637E+02
0.135E+02	0.169E-01	0.441E+00	0.368E-01	0.954E-02	0.0	-0.933E+00	0.654E+02
0.138E+02	0.150E-01	0.424E+00	0.383E-01	0.106E-01	0.0	-0.114E+01	0.671E+02
0.140E+02	-0.640E-02	0.411E+00	0.394E-01	0.115E-01	0.0	-0.136E+01	0.687E+02
0.143E+02	-0.726E-01	0.409E+00	0.353E-01	0.104E-01	0.0	-0.158E+01	0.704E+02
0.145E+02	-0.122E+00	0.423E+00	0.231E-01	0.644E-02	0.0	-0.174E+01	0.720E+02
0.148E+02	-0.102E+00	0.439E+00	0.801E-02	0.209E-02	0.0	-0.178E+01	0.737E+02
0.150E+02	-0.158E-01	0.441E+00	0.0	0.0	0.0	-0.174E+01	0.753E+02
0.153E+02	0.769E-02	0.431E+00	0.0	0.0	0.0	-0.168E+01	0.769E+02
0.155E+02	0.582E-02	0.418E+00	0.0	0.0	0.0	-0.162E+01	0.785E+02
0.158E+02	0.474E-02	0.406E+00	0.0	0.0	0.0	-0.157E+01	0.800E+02
0.160E+02	0.404E-02	0.394E+00	0.0	0.0	0.0	-0.153E+01	0.816E+02
0.163E+02	0.352E-02	0.382E+00	0.0	0.0	0.0	-0.148E+01	0.831E+02
0.165E+02	0.313E-02	0.371E+00	0.0	0.0	0.0	-0.144E+01	0.846E+02
0.168E+02	0.280E-02	0.359E+00	0.0	0.0	0.0	-0.141E+01	0.861E+02
0.170E+02	0.252E-02	0.349E+00	0.0	0.0	0.0	-0.137E+01	0.875E+02
0.173E+02	0.227E-02	0.338E+00	0.0	0.0	0.0	-0.134E+01	0.890E+02
0.175E+02	0.206E-02	0.328E+00	0.0	0.0	0.0	-0.131E+01	0.904E+02
0.178E+02	0.187E-02	0.318E+00	0.0	0.0	0.0	-0.128E+01	0.918E+02
0.180E+02	0.171E-02	0.308E+00	0.0	0.0	0.0	-0.125E+01	0.931E+02
0.183E+02	0.155E-02	0.298E+00	0.0	0.0	0.0	-0.123E+01	0.945E+02
0.185E+02	0.142E-02	0.289E+00	0.0	0.0	0.0	-0.120E+01	0.958E+02
0.188E+02	0.130E-02	0.281E+00	0.0	0.0	0.0	-0.118E+01	0.971E+02
0.190E+02	0.119E-02	0.272E+00	0.0	0.0	0.0	0.116E+01	0.984E+02
0.193E+02	0.109E-02	0.263E+00	0.0	0.0	0.0	-0.114E+01	0.997E+02
0.195E+02	0.101E-02	0.254E+00	0.0	0.0	0.0	-0.112E+01	0.101E+03
0.198E+02	0.925E-03	0.246E+00	0.0	0.0	0.0	-0.110E+01	0.102E+03

1

RAD P-PER: MID TO COIL

Z = 0.0 0.56 1.11 1.67 2.22 2.78 3.33 3.89 4.45 5.00 5.56 6.11 6.67 7.22 7.78 8.33 8.89 9.45 10.00 10.56 11.

68.

4.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.75	0.0	0.0	0.0	0.0	0.000	0.001	0.002	0.002	0.000	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.25	0.004	0.004	0.005	0.006	0.009	0.011	0.012	0.012	0.009	0.006	0.001	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.75	0.022	0.022	0.023	0.023	0.023	0.021	0.020	0.017	0.014	0.011	0.007	0.002	0.016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.25	0.029	0.029	0.028	0.028	0.027	0.025	0.024	0.022	0.019	0.016	0.012	0.006	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.75	0.032	0.032	0.032	0.031	0.030	0.029	0.028	0.026	0.023	0.020	0.010	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.25	0.035	0.035	0.035	0.034	0.034	0.033	0.031	0.029	0.020	0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.75	0.038	0.038	0.033	0.037	0.036	0.033	0.024	0.012	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.25	0.035	0.034	0.032	0.027	0.019	0.010	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.75	0.008	0.007	0.004	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RS

ZS

SI

SIV

STP

2.8000E+01

9.5000E+00

-6.8994E-01

1.4291E+02

1.4222E+02

R; T=800.82/807.96 17:47:55

1

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EBTI KT8
IMX = 181  XMAX = 45.000000
KMXM1 = 41  YMAX = 22.225006
IBUG = 0    IBUG OF ZERO GIVES MIN DIAG PRINT
NOTE THAT KMX = 42    LMX = 7602
SEP = 44.449997  RADIUS OF LOOP = 9.525000
NO COIL PAIRS NP = 4
NO PLASMA PAIRS FOR MULTIPOLE NPM = 5
MAX NO OF OVERALL ITERATIONS ITERMX = 20
MAX NO OF ITERATIONS FOR IE INMX = 25
DOUBLE INMX WHEN ITER A MULT. OF IDOUB= 5
TO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION
IT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT
KCUR = 38    ICUT = 36
ORC = 1.900000

```

```

DATA FOR CALP
ITNSC = 0    SLOP = 1.000000
INPUT = 1
RADII FOR SI DEP OF TENSOR PART
RSI1 = 11.00    RSI2 = 13.00    RSI3 = 13.00    RSI4 = 15.00
RC = 0.60
SINCE INPUT EQUALS ONE WE HAVE THE TAU CONST CASE
S = 0.800000
CONSTANTS FOR JDISP
IMNDL = 20    IMXDL = 80    IMDEL = 2
IBC = 1
RMSC = 8.000000
JCUT = 10
IF IBC IS ZERO FLUX CONSERVING RC ARE USED
RMSC IS USED FOR THE MULTIPOLE EXPANSION
JCUT IS THE NUMBER OF TERMS IN THE MULTIPOLE EXPANSION

```

(Output from EQUIL for 18% "beta" case)

```

ITER = 0      B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.657514E-01
N = 25 RES = 0.200650E-01
ITER = 1      B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.493689E-01
N = 25 RES = 0.163373E-01
ITER = 2      B AT ORIGIN = 0.100012E+01
N = 1 RES = 0.403318E-01
N = 25 RES = 0.143359E-01
ITER = 3      B AT ORIGIN = 0.100000E+01
N = 1 RES = 0.312744E-01
N = 25 RES = 0.125747E-01
ITER = 4      B AT ORIGIN = 0.999930E+00
N = 1 RES = 0.248373E-01
N = 50 RES = 0.430526E-02
ITER = 5      B AT ORIGIN = 0.999789E+00
N = 1 RES = 0.199719E-01
N = 50 RES = 0.347072E-02
ITER = 6      B AT ORIGIN = 0.999903E+00
N = 1 RES = 0.165749E-01
N = 50 RES = 0.294961E-02
ITER = 7      B AT ORIGIN = 0.999982E+00
N = 1 RES = 0.137704E-01
N = 50 RES = 0.253894E-02
ITER = 8      B AT ORIGIN = 0.100004E+01
N = 1 RES = 0.115135E-01
N = 50 RES = 0.220934E-02
ITER = 9      B AT ORIGIN = 0.100008E+01
N = 1 RES = 0.970452E-02
N = 100 RES = 0.107873E-02
ITER = 10     B AT ORIGIN = 0.100016E+01
N = 1 RES = 0.794937E-02
N = 100 RES = 0.798922E-03
ITER = 11     B AT ORIGIN = 0.100022E+01
N = 1 RES = 0.745048E-02
N = 100 RES = 0.615208E-03
ITER = 12     B AT ORIGIN = 0.100027E+01
N = 1 RES = 0.645208E-02
N = 100 RES = 0.482136E-03
ITER = 13     B AT ORIGIN = 0.100030E+01
N = 1 RES = 0.557166E-02
N = 100 RES = 0.382962E-03
ITER = 14     B AT ORIGIN = 0.100033E+01
N = 1 RES = 0.481144E-02
N = 200 RES = 0.202673E-03
ITER = 15     B AT ORIGIN = 0.100037E+01
N = 1 RES = 0.426033E-02
N = 200 RES = 0.121323E-03
ITER = 16     B AT ORIGIN = 0.100039E+01
N = 1 RES = 0.371663E-02
N = 200 RES = 0.803160E-04
ITER = 17     B AT ORIGIN = 0.100040E+01
N = 1 RES = 0.319615E-02
N = 200 RES = 0.583668E-04
ITER = 18     B AT ORIGIN = 0.100041E+01
N = 1 RES = 0.273660E-02
N = 200 RES = 0.443551E-04
ITER = 19     B AT ORIGIN = 0.100041E+01
N = 1 RES = 0.234167E-02
N = 400 RES = 0.175014E-04

```

RNID	CURD	MODB	P-PERP	P-PARA	DLOB	SI	SIV
0.475E+01	-0.471E-03	0.915E+00	0.0	0.0	0.0	-0.167E-01	0.108E+02
0.500E+01	-0.507E-03	0.906E+00	0.0	0.0	0.0	-0.179E-01	0.119E+02
0.525E+01	-0.573E-03	0.897E+00	0.0	0.0	0.0	-0.190E-01	0.131E+02
0.550E+01	-0.617E-03	0.887E+00	0.0	0.0	0.0	-0.199E-01	0.143E+02
0.575E+01	-0.697E-03	0.878E+00	0.0	0.0	0.0	-0.206E-01	0.155E+02
0.600E+01	-0.754E-03	0.869E+00	0.0	0.0	0.0	-0.211E-01	0.168E+02
0.625E+01	-0.850E-03	0.858E+00	0.0	0.0	0.0	-0.214E-01	0.181E+02
0.650E+01	-0.922E-03	0.848E+00	0.0	0.0	0.0	-0.213E-01	0.195E+02
0.675E+01	-0.104E-02	0.837E+00	0.0	0.0	0.0	-0.208E-01	0.209E+02
0.700E+01	-0.113E-02	0.826E+00	0.0	0.0	0.0	-0.199E-01	0.223E+02
0.725E+01	-0.128E-02	0.815E+00	0.0	0.0	0.0	-0.184E-01	0.238E+02
0.750E+01	-0.140E-02	0.804E+00	0.0	0.0	0.0	-0.163E-01	0.252E+02
0.775E+01	-0.158E-02	0.793E+00	0.0	0.0	0.0	-0.134E-01	0.268E+02
0.800E+01	-0.174E-02	0.781E+00	0.0	0.0	0.0	-0.972E-02	0.283E+02
0.825E+01	-0.196E-02	0.769E+00	0.0	0.0	0.0	-0.500E-02	0.299E+02
0.850E+01	-0.216E-02	0.758E+00	0.0	0.0	0.0	0.896E-03	0.315E+02
0.875E+01	-0.244E-02	0.746E+00	0.0	0.0	0.0	0.813E-02	0.331E+02
0.900E+01	-0.271E-02	0.734E+00	0.0	0.0	0.0	0.169E-01	0.347E+02
0.925E+01	-0.306E-02	0.722E+00	0.0	0.0	0.0	0.275E-01	0.364E+02
0.950E+01	-0.340E-02	0.710E+00	0.0	0.0	0.0	0.402E-01	0.380E+02
0.975E+01	-0.384E-02	0.698E+00	0.0	0.0	0.0	0.553E-01	0.397E+02
0.100E+02	-0.428E-02	0.686E+00	0.0	0.0	0.0	0.731E-01	0.414E+02
0.103E+02	-0.482E-02	0.675E+00	0.0	0.0	0.0	0.941E-01	0.431E+02
0.105E+02	-0.537E-02	0.663E+00	0.0	0.0	0.0	0.119E+00	0.448E+02
0.108E+02	-0.603E-02	0.651E+00	0.0	0.0	0.0	0.147E+00	0.465E+02
0.110E+02	-0.670E-02	0.640E+00	0.0	0.0	0.0	0.181E+00	0.483E+02
0.113E+02	-0.749E-02	0.629E+00	0.0	0.0	0.0	0.220E+00	0.500E+02
0.115E+02	-0.828E-02	0.617E+00	0.0	0.0	0.0	0.265E+00	0.517E+02
0.118E+02	0.950E-02	0.604E+00	0.0	0.0	0.0	0.317E+00	0.534E+02
0.120E+02	0.642E-01	0.582E+00	0.525E-02	0.797E-04	0.0	0.364E+00	0.552E+02
0.123E+02	0.138E+00	0.544E+00	0.202E-01	0.986E-03	0.0	0.362E+00	0.569E+02
0.125E+02	0.188E+00	0.491E+00	0.436E-01	0.436E-02	0.0	0.254E+00	0.586E+02
0.128E+02	0.170E+00	0.432E+00	0.680E-01	0.111E-01	0.0	-0.402E-02	0.603E+02
0.130E+02	0.961E-01	0.387E+00	0.842E-01	0.182E-01	0.0	-0.404E+00	0.620E+02
0.133E+02	0.662E-02	0.363E+00	0.893E-01	0.220E-01	0.0	-0.891E+00	0.637E+02
0.135E+02	-0.761E-01	0.359E+00	0.845E-01	0.213E-01	0.0	-0.139E+01	0.654E+02
0.138E+02	-0.140E+00	0.373E+00	0.714E-01	0.167E-01	0.0	-0.184E+01	0.671E+02
0.140E+02	-0.169E+00	0.399E+00	0.526E-01	0.106E-01	0.0	-0.217E+01	0.687E+02
0.143E+02	-0.153E+00	0.428E+00	0.329E-01	0.550E-02	0.0	-0.236E+01	0.704E+02
0.145E+02	-0.110E+00	0.450E+00	0.161E-01	0.230E-02	0.0	-0.242E+01	0.720E+02
0.148E+02	-0.552E-01	0.459E+00	0.459E-02	0.613E-03	0.0	-0.237E+01	0.737E+02
0.150E+02	-0.827E-03	0.453E+00	0.0	0.0	0.0	-0.227E+01	0.753E+02
0.153E+02	0.126E-01	0.441E+00	0.0	0.0	0.0	-0.218E+01	0.769E+02
0.155E+02	0.103E-01	0.426E+00	0.0	0.0	0.0	-0.209E+01	0.785E+02
0.158E+02	0.858E-02	0.413E+00	0.0	0.0	0.0	-0.201E+01	0.800E+02
0.160E+02	0.738E-02	0.400E+00	0.0	0.0	0.0	-0.193E+01	0.816E+02
0.163E+02	0.637E-02	0.388E+00	0.0	0.0	0.0	-0.187E+01	0.831E+02
0.165E+02	0.560E-02	0.376E+00	0.0	0.0	0.0	-0.181E+01	0.846E+02
0.168E+02	0.489E-02	0.364E+00	0.0	0.0	0.0	-0.175E+01	0.861E+02
0.170E+02	0.436E-02	0.353E+00	0.0	0.0	0.0	-0.170E+01	0.875E+02
0.173E+02	0.383E-02	0.342E+00	0.0	0.0	0.0	-0.165E+01	0.890E+02
0.175E+02	0.344E-02	0.331E+00	0.0	0.0	0.0	-0.160E+01	0.904E+02
0.178E+02	0.304E-02	0.321E+00	0.0	0.0	0.0	-0.156E+01	0.918E+02
0.180E+02	0.276E-02	0.310E+00	0.0	0.0	0.0	-0.152E+01	0.931E+02
0.183E+02	0.244E-02	0.301E+00	0.0	0.0	0.0	-0.149E+01	0.945E+02
0.185E+02	0.224E-02	0.291E+00	0.0	0.0	0.0	-0.145E+01	0.958E+02
0.188E+02	0.199E-02	0.283E+00	0.0	0.0	0.0	-0.142E+01	0.971E+02
0.190E+02	0.183E-02	0.273E+00	0.0	0.0	0.0	-0.139E+01	0.984E+02
0.193E+02	0.163E-02	0.264E+00	0.0	0.0	0.0	-0.137E+01	0.997E+02
0.195E+02	0.152E-02	0.256E+00	0.0	0.0	0.0	-0.134E+01	0.101E+03
0.198E+02	0.135E-02	0.247E+00	0.0	0.0	0.0	-0.131E+01	0.102E+03

RAD P-PER: MID TO COIL

Z = 0.0 0.56 1.11 1.67 2.22 2.78 3.33 3.89 4.45 5.00 5.56 6.11 6.67 7.22 7.78 8.33 8.89 9.45 10.00 10.56 11.

93

4.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.25	0.020	0.021	0.021	0.022	0.022	0.020	0.016	0.006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.75	0.068	0.067	0.067	0.066	0.062	0.055	0.041	0.024	0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.25	0.089	0.089	0.085	0.078	0.067	0.051	0.032	0.015	0.005	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.75	0.071	0.069	0.063	0.053	0.039	0.024	0.011	0.003	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.25	0.033	0.031	0.026	0.018	0.010	0.004	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.75	0.005	0.004	0.002	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RS	ZS	SI	SIV	STP
2.8000E+01	9.5000E+00	-7.8596E-01	1.4291E+02	1.4213E+02

R; T=798.82/811.35 17:40:40

1

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EBTI KT8
IMX = 181 XMAX = 45.000000
KMXM1 = 41 YMAX = 22.225006
IBUG = 0 IBUG OF ZERO GIVES MIN DIAG PRINT
NOTE THAT KMX = 42 LMX = 7602
SEP = 44.449997 RADIUS OF LOOP = 9.525000
NO COIL PAIRS NP = 4
NO PLASMA PAIRS FOR MULTIPOLE NPM = 5
MAX NO OF OVERALL ITERATIONS ITERMX = 20
MAX NO OF ITERATIONS FOR DE INMX = 25
DOUBLE INMX WHEN ITER A MULT. OF IDOUB= 5
TO AVOID THE SINGULARITY FOR THE VAC FLUX FUNCTION
IT IS SET TO ZERO FOR K GE KCUT AND I GE ICUT
K CUT = 38 ICUT = 36
ORC = 1.900000

```

DATA FOR CALP

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ITNSC = 0 SLOP = 1.000000
INPUT = 1
RADII FOR SI DEP OF TENSOR PART
RSI1 = 11.00 RSI2 = 12.00 RSI3 = 14.00 RSI4 = 15.00
BC = 0.60
SINCE INPUT EQUALS ONE WE HAVE THE TAU CONST CASE
S = 0.800000
CONSTANTS FOR JDISP
IMNDL = 20 INXDL = 80 IMDEL = 2
IBC = 1
RMSC = 8.000000
JCUT = 10
IF IBC IS ZERO FLUX CONSERVING BC ARE USED
RMSC IS USED FOR THE MULTIPOLE EXPANSION
JCUT IS THE NUMRER OF TERMS IN THE MULTIPOLE EXPANSION

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(Output from EQUIL for 23% "beta" case)

ITER =	0	B AT ORIGIN =	0.100012E+01
N =	1	RES =	0.874668E-01
N =	25	RES =	0.266914E-01
ITER =	1	B AT ORIGIN =	0.100012E+01
N =	1	RES =	0.734369E-01
N =	25	RES =	0.241016E-01
ITER =	2	B AT ORIGIN =	0.100011E+01
N =	1	RES =	0.636881E-01
N =	25	RES =	0.222830E-01
ITER =	3	B AT ORIGIN =	0.999948E+00
N =	1	RES =	0.527849E-01
N =	25	RES =	0.195203E-01
ITER =	4	B AT ORIGIN =	0.999831E+00
N =	1	RES =	0.440358E-01
N =	50	RES =	0.643954E-02
ITER =	5	B AT ORIGIN =	0.999589E+00
N =	1	RES =	0.351536E-01
N =	50	RES =	0.546023E-02
ITER =	6	B AT ORIGIN =	0.999746E+00
N =	1	RES =	0.171483E-01
N =	50	RES =	0.450835E-02
ITER =	7	B AT ORIGIN =	0.999857E+00
N =	1	RES =	0.210369E-01
N =	50	RES =	0.394541E-02
ITER =	8	B AT ORIGIN =	0.999908E+00
N =	1	RES =	0.243801E-01
N =	50	RES =	0.352267E-02
ITER =	9	B AT ORIGIN =	0.999948E+00
N =	1	RES =	0.104967E-01
N =	100	RES =	0.163332E-02
ITER =	10	B AT ORIGIN =	0.100004E+01
N =	1	RES =	0.666540E-02
N =	100	RES =	0.115009E-02
ITER =	11	B AT ORIGIN =	0.100011E+01
N =	1	RES =	0.182192E-01
N =	100	RES =	0.966513E-03
ITER =	12	B AT ORIGIN =	0.100018E+01
N =	1	RES =	0.159997E-01
N =	100	RES =	0.815854E-03
ITER =	13	B AT ORIGIN =	0.100025E+01
N =	1	RES =	0.141629E-01
N =	100	RES =	0.691086E-03
ITER =	14	B AT ORIGIN =	0.100030E+01
N =	1	RES =	0.126106E-01
N =	200	RES =	0.382972E-03
ITER =	15	B AT ORIGIN =	0.100039E+01
N =	1	RES =	0.115560E-01
N =	200	RES =	0.251327E-03
ITER =	16	B AT ORIGIN =	0.100044E+01
N =	1	RES =	0.105046E-01
N =	200	RES =	0.182810E-03
ITER =	17	B AT ORIGIN =	0.100047E+01
N =	1	RES =	0.944036E-02
N =	200	RES =	0.143187E-03
ITER =	18	B AT ORIGIN =	0.100049E+01
N =	1	RES =	0.843725E-02
N =	200	RES =	0.118888E-03
ITER =	19	B AT ORIGIN =	0.100051E+01
N =	1	RES =	0.756030E-02
N =	400	RES =	0.467685E-04

RMID	CURD	NODB	P-PERP	P-PARA	DLOB	SI	SIV
0.475E+01	-0.717E-03	0.914E+00	0.0	0.0	0.0	-0.232E-01	0.108E+02
0.500E+01	-0.747E-03	0.906E+00	0.0	0.0	0.0	-0.247E-01	0.119E+02
0.525E+01	-0.864E-03	0.897E+00	0.0	0.0	0.0	-0.260E-01	0.131E+02
0.550E+01	-0.904E-03	0.887E+00	0.0	0.0	0.0	-0.272E-01	0.143E+02
0.575E+01	-0.104E-02	0.878E+00	0.0	0.0	0.0	-0.280E-01	0.155E+02
0.600E+01	-0.110E-02	0.869E+00	0.0	0.0	0.0	-0.285E-01	0.168E+02
0.625E+01	-0.126E-02	0.858E+00	0.0	0.0	0.0	-0.287E-01	0.181E+02
0.650E+01	-0.133E-02	0.848E+00	0.0	0.0	0.0	-0.283E-01	0.195E+02
0.675E+01	-0.152E-02	0.837E+00	0.0	0.0	0.0	-0.273E-01	0.209E+02
0.700E+01	-0.162E-02	0.827E+00	0.0	0.0	0.0	-0.257E-01	0.223E+02
0.725E+01	-0.184E-02	0.816E+00	0.0	0.0	0.0	-0.233E-01	0.238E+02
0.750E+01	-0.198E-02	0.805E+00	0.0	0.0	0.0	-0.200E-01	0.252E+02
0.775E+01	-0.225E-02	0.793E+00	0.0	0.0	0.0	-0.156E-01	0.268E+02
0.800E+01	-0.242E-02	0.782E+00	0.0	0.0	0.0	-0.990E-02	0.283E+02
0.825E+01	-0.275E-02	0.771E+00	0.0	0.0	0.0	-0.284E-02	0.299E+02
0.850E+01	-0.297E-02	0.759E+00	0.0	0.0	0.0	0.587E-02	0.315E+02
0.875E+01	-0.337E-02	0.747E+00	0.0	0.0	0.0	0.165E-01	0.331E+02
0.900E+01	-0.367E-02	0.736E+00	0.0	0.0	0.0	0.292E-01	0.347E+02
0.925E+01	-0.415E-02	0.724E+00	0.0	0.0	0.0	0.444E-01	0.364E+02
0.950E+01	-0.453E-02	0.713E+00	0.0	0.0	0.0	0.625E-01	0.380E+02
0.975E+01	-0.511E-02	0.701E+00	0.0	0.0	0.0	0.837E-01	0.397E+02
0.100E+02	-0.560E-02	0.689E+00	0.0	0.0	0.0	0.109E+00	0.414E+02
0.103E+02	-0.631E-02	0.678E+00	0.0	0.0	0.0	0.138E+00	0.431E+02
0.105E+02	-0.692E-02	0.667E+00	0.0	0.0	0.0	0.172E+00	0.448E+02
0.108E+02	-0.775E-02	0.655E+00	0.0	0.0	0.0	0.211E+00	0.465E+02
0.110E+02	-0.850E-02	0.644E+00	0.0	0.0	0.0	0.257E+00	0.483E+02
0.113E+02	-0.948E-02	0.634E+00	0.0	0.0	0.0	0.309E+00	0.500E+02
0.115E+02	-0.104E-01	0.623E+00	0.0	0.0	0.0	0.370E+00	0.517E+02
0.118E+02	0.117E-01	0.610E+00	0.0	0.0	0.0	0.439E+00	0.534E+02
0.120E+02	0.724E-01	0.586E+00	0.648E-02	0.747E-04	0.0	0.501E+00	0.552E+02
0.123E+02	0.122E+00	0.549E+00	0.233E-01	0.102E-02	0.0	0.510E+00	0.569E+02
0.125E+02	0.144E+00	0.503E+00	0.426E-01	0.373E-02	0.0	0.424E+00	0.586E+02
0.128E+02	0.148E+00	0.453E+00	0.620E-01	0.867E-02	0.0	0.222E+00	0.603E+02
0.130E+02	0.144E+00	0.404E+00	0.787E-01	0.153E-01	0.0	-0.103E+00	0.620E+02
0.133E+02	0.141E+00	0.357E+00	0.929E-01	0.235E-01	0.0	-0.552E+00	0.637E+02
0.135E+02	0.123E+00	0.311E+00	0.105E+00	0.333E-01	0.0	-0.113E+01	0.654E+02
0.138E+02	0.691E-01	0.274E+00	0.114E+00	0.424E-01	0.0	-0.182E+01	0.671E+02
0.140E+02	-0.389E-01	0.259E+00	0.117E+00	0.466E-01	0.0	-0.258E+01	0.687E+02
0.143E+02	-0.240E+00	0.282E+00	0.105E+00	0.379E-01	0.0	-0.332E+01	0.704E+02
0.145E+02	-0.422E+00	0.354E+00	0.681E-01	0.175E-01	0.0	-0.386E+01	0.720E+02
0.148E+02	-0.327E+00	0.436E+00	0.211E-01	0.333E-02	0.0	-0.403E+01	0.737E+02
0.150E+02	-0.468E-01	0.469E+00	0.0	0.0	0.0	-0.389E+01	0.753E+02
0.153E+02	0.272E-01	0.461E+00	0.0	0.0	0.0	-0.371E+01	0.769E+02
0.155E+02	0.206E-01	0.444E+00	0.0	0.0	0.0	-0.354E+01	0.785E+02
0.158E+02	0.164E-01	0.428E+00	0.0	0.0	0.0	-0.340E+01	0.800E+02
0.160E+02	0.137E-01	0.414E+00	0.0	0.0	0.0	-0.327E+01	0.816E+02
0.163E+02	0.116E-01	0.400E+00	0.0	0.0	0.0	-0.315E+01	0.831E+02
0.165E+02	0.101E-01	0.387E+00	0.0	0.0	0.0	-0.305E+01	0.846E+02
0.168E+02	0.878E-02	0.374E+00	0.0	0.0	0.0	-0.295E+01	0.861E+02
0.170E+02	0.781E-02	0.362E+00	0.0	0.0	0.0	-0.286E+01	0.875E+02
0.173E+02	0.681E-02	0.350E+00	0.0	0.0	0.0	-0.277E+01	0.890E+02
0.175E+02	0.615E-02	0.338E+00	0.0	0.0	0.0	-0.269E+01	0.904E+02
0.178E+02	0.537E-02	0.328E+00	0.0	0.0	0.0	-0.262E+01	0.918E+02
0.180E+02	0.490E-02	0.317E+00	0.0	0.0	0.0	-0.255E+01	0.931E+02
0.183E+02	0.429E-02	0.306E+00	0.0	0.0	0.0	-0.249E+01	0.945E+02
0.185E+02	0.396E-02	0.297E+00	0.0	0.0	0.0	-0.243E+01	0.958E+02
0.188E+02	0.347E-02	0.288E+00	0.0	0.0	0.0	-0.238E+01	0.971E+02
0.190E+02	0.324E-02	0.278E+00	0.0	0.0	0.0	-0.233E+01	0.984E+02
0.193E+02	0.283E-02	0.268E+00	0.0	0.0	0.0	-0.228E+01	0.997E+02
0.195E+02	0.268E-02	0.260E+00	0.0	0.0	0.0	-0.223E+01	0.101E+03
0.198E+02	0.233E-02	0.251E+00	0.0	0.0	0.0	-0.219E+01	0.102E+03

RAD P-PER: MID TO COIL

Z = 0.0 0.56 1.11 1.67 2.22 2.78 3.33 3.89 4.45 5.00 5.56 6.11 6.67 7.22 7.78 8.33 8.89 9.45 10.00 10.56 11.

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4.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.25	0.023	0.023	0.023	0.023	0.021	0.019	0.016	0.010	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12.75	0.062	0.061	0.061	0.061	0.060	0.058	0.053	0.044	0.027	0.003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.25	0.093	0.093	0.093	0.092	0.091	0.086	0.076	0.050	0.014	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.75	0.114	0.113	0.112	0.109	0.101	0.078	0.037	0.005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.25	0.105	0.102	0.092	0.071	0.038	0.009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14.75	0.021	0.017	0.009	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RS
2.8000E+01

ZS
9.5000E+00

SI
-1.2915E+00

SIV
1.4291E+02

STP
1.4162E+02

BUMCAL program

The BUMCAL program calculates the flux linkage for the diamagnetic pickup loop for a bumpy cylinder current sheet model. The next page gives a sample interactive terminal session using BUMCAL. The following pages provide a FORTRAN listing for BUMCAL and the ideal solenoid code, SOLBA, called by it.

LOAD BUNCAL :NOMAP START
EXECUTION BEGINS...

ENTER NOC,RS,SL,SEP,:

?

.5 11 10 44.45

\$BUNCAL

RF= 28.0000000000000000 ,ZF1= 9.5000000000000000 ,RS= 11.0000000000000000 ,SL= 10.0000000000000000 ,

NOC= 5,SEP= 44.4499999999999993 ,APT= .619572240251832690

\$END

.619572240251832690

ENTER NOC,RS,SL,SEP,:

?

.-1/

R;

.

C	PROGRAM BUMCAL K.H.CARPENTER 22JAN81	BUM00
C	KHC 06FEB81 CORRECT LOOP ON NOC TO START AT 1.	BUM00
C	OUTPUTS DATA NEEDED TO CALIBRATE A BUMPY CYLINDER DIAMAGNETIC	BUM00
C	DIAGNOSTIC USING A CURRENT SHEET MODEL.	BUM00
	IMPLICIT REAL*8 (A-H,O-Z)	BUM00
	COMMON/CISOL/RS,SL,RF,ZF,BR,BZ,AP	BUM00
	NAMELIST/BUMCAL/RF,ZF1,RS,SL,NOC,SEP,APT	BUM00
C	SEP=44.45D0	BUM00
	RF=28.D0	BUM00
	ZF1=9.5D0	BUM00
10	WRITE(5,20)	BUM00
20	FORMAT(' ENTER NOC,RS,SL,SEP,:)')	BUM00
	READ(5,*)NOC,RS,SL,SEP	BUM00
	IF(NOC.LT.0)STOP	BUM00
	ZF=ZF1	BUM00
	CALL SOLBA	BUM00
	APT=AP	BUM00
	IF(NOC.LE.1)GO TO 40	BUM00
	NOC1=NOC-1	BUM00
	DO 30 K=1,NOC1	BUM00
	ZF=ZF1+K*SEP	BUM00
	CALL SOLBA	BUM00
	APT=APT+AP	BUM00
	ZF=ZF1-K*SEP	BUM00
	CALL SOLBA	BUM00
30	APT=APT+AP	BUM00
40	WRITE(6,BUMCAL)	BUM00
	WRITE(5,*)APT	BUM00
	GO TO 10	BUM00
	END	BUM00

```

SUBROUTINE SOLBA
IMPLICIT REAL*8 (A-H,O-Z)
COMMON/CISOL/RS,SL,RF,ZF,BR,BZ,AP
C K.H.CARPENTER 29SEP80  UMR DEPT. OF EE.
C****
C   Calculates the B-field and A-field components for an ideal
C   solenoid using the method of M.W.Garrett, JAP Vol.34 p2567 (1963).
C   This version is an adaption of the BIDSOL subroutine written by
C   Tommy Tucker of Oak Ridge Nat. Lab., Computer Sciences Div.
C   (BIDSOL converted to double precision, normalization changed, and
C   calculation of vector potential added.)
C****
C   Input values:
C       RS - RADIUS OF SOLENOID CURRENT SHEET
C       SL - LENGTH OF SOLENOID CURRENT SHEET
C       RF - FIELD POINT RADIAL DISTANCE FROM SOLENOID AXIS
C       ZF - FIELD POINT AXIAL DISTANCE FROM CENTER OF SOLENOID
C   (Input values can be in any unit of length, but all four must
C   be in the same units.)
C   Output values:
C       BR - NORMALIZED RADIAL FIELD COMPONENT
C       BZ - NORMALIZED AXIAL FIELD COMPONENT
C       AP - NORMALIZED ANGULAR VECTOR POTENTIAL COMPONENT
C   To obtain dimensional values for components:
C       Multiply all components by surface current density and
C       multiply all components by permeability divided by 4 times pi.
C       In addition, multiply AP by the dimensional length of the
C       solenoid current sheet.
C****
DATA PI/3.14159 265389 793238 D0/
DATA TOL/1.D-12/, CUT/5.D-4/, CUTSQ/25.D-8/
RSMRF=RS-RF
RSPRF=RF+RS
RSPFSQ=RSPRF**2
DZ1=ZF-0.5D0*SL
DZ2=DZ1+SL
DZ1SQ=DZ1*DZ1
R1SQ=RSPFSQ+DZ1SQ
R1=DSQRT(R1SQ)
DZ2SQ=DZ2*DZ2
R2SQ=RSPFSQ+DZ2SQ
R2=DSQRT(R2SQ)
IF(RF.GT.1.0D-6)GO TO 20
C ON AXIS THE CALCULATION SIMPLIFIES TO
BZ=2.D0*PI*(DZ2/R2-DZ1/R1)
BR=0.D0
AP=0.D0
RETURN
20 CONTINUE
RSRFT4=RS*RF*4.D0
PAR1=RSRFT4/R1SQ
CMOD1=DSQRT(1.D0-PAR1)
A1=1.D0
B1=CMOD1
CPRIME=RSMRF/RSPRF

```


	CCHAR=CPRIME**2	SOL00
	IF(CCHAR.GE.CUTSQ)GO TO 30	SOL00
C	TO CALCULATE BZ AT OR NEAR THE RADIUS OF THE CURRENT SHEET,	SOL00
C	MODIFY CCHAR TO ALLOW THE ITERATION TO PROCEED WITHOUT	SOL00
C	ZERO DIVIDED OR OVERFLOW. THE BZ CALCULATION IS CORRECTED	SOL00
C	FOR THE SMALL ERROR INTRODUCED AT THE END OF THE ROUTINE.	SOL00
	CPRIMA=CUT	SOL00
	IF(RSMRF.LT.0.D0)CPRIMA=-CPRIMA	SOL00
	CCHAR=CUTSQ	SOL00
30	CONTINUE	SOL00
	D1=CCHAR/CMOD1	SOL00
	CHAR=1.D0-CCHAR	SOL00
	E1=CHAR/CCHAR	SOL00
	F1=0.D0	SOL00
	S1=0.D0	SOL00
	PAR2=RSRFT4/R2SQ	SOL00
	CMOD2=DSQRT(1.D0-PAR2)	SOL00
	A2=1.D0	SOL00
	B2=CMOD2	SOL00
	D2=CCHAR/CMOD2	SOL00
	E2=E1	SOL00
	F2=0.D0	SOL00
	S2=0.D0	SOL00
	TWOP=1.D0	SOL00
100	CONTINUE	SOL00
	TWOP=TWOP*2.D0	SOL00
	C=A1	SOL00
	A1=(A1+B1)*0.5D0	SOL00
	B1=DSQRT(C*B1)	SOL00
	CSQ1=(C-A1)**2	SOL00
	S1=S1+CSQ1*TWOP	SOL00
	C=A2	SOL00
	A2=(A2+B2)*0.5D0	SOL00
	B2=DSQRT(C*B2)	SOL00
	CSQ2=(C-A2)**2	SOL00
	S2=S2+CSQ2*TWOP	SOL00
	C=F1	SOL00
	F1=(E1+F1)*0.5D0	SOL00
	DPONE=D1+1.D0	SOL00
	E1=(D1*E1+C)/DPONE	SOL00
	D1=B1*0.25D0*DPONE*DPONE/(A1*D1)	SOL00
	C=F2	SOL00
	F2=(E2+F2)*0.5D0	SOL00
	DPONE=D2+1.D0	SOL00
	E2=(D2*E2+C)/DPONE	SOL01
	D2=B2*0.25D0*DPONE*DPONE/(A2*D2)	SOL01
	IF((CSQ1.GT.TOL).OR.(CSQ2.GT.TOL))GO TO 100	SOL01
C	ONE ADDITIONAL 'A' STEP WILL HALVE THE ERROR	SOL01
	A1=(A1+B1)*0.5D0	SOL01
	A2=(A2+B2)*0.5D0	SOL01
C	BR CAN NOW BE CALCULATED FROM ELLIPTIC INTEGRAL VALUES	SOL01
	BR=0.5D0*PI*(R2*S2/A2-R1*S1/A1)/RF	SOL01
C	CONTINUE ITERATIONS TO IMPROVE ACCURACY OF 3RD COMPLETE ELL. INTEGRALS	SOL01
200	CONTINUE	SOL01
	C=F1	SOL01

F1=(E1+F1)*0.5D0	SOL01
DPONE=D1+1.D0	SOL01
E1=(D1*E1+C)/DPONE	SOL01
D1=0.25D0*DPONE*DPONE/D1	SOL01
C=F2	SOL01
F2=(E2+F2)*0.5D0	SOL01
DPONE=D2+1.D0	SOL01
E2=(D2*E2+C)/DPONE	SOL01
D2=0.25D0*DPONE*DPONE/D2	SOL01
IF((D1*D2-1.D0).GT.TOL)GO TO 200	SOL01
F1=(E1+F1)*0.5D0	SOL01
F2=(E2+F2)*0.5D0	SOL01
C BZ AND AP CAN NOW BE CALCULATED	SOL01
BZ=PI*(DZ2*(RS+RS+RSMRF*F2)/(RSPRF*R2*A2)-	SOL01
> DZ1*(RS+RS+RSMRF*F1)/(RSPRF*R1*A1))	SOL01
IF((CCHAR.EQ.CUTSQ).AND.(CPRIME.NE.0.D0))BZ=BZ+PI*	SOL01
> DABS(CPRIMA-CPRIME)/CPRIMA*(DZ2/(R2*CMOD2)-DZ1/(R1*CMOD1))	SOL01
RSMRFS=RSMRF**2	SOL01
AP=(DZ2*(R2*0.5D0*(PAR2+S2)-RSMRFS*F2/R2)/A2 -	SOL01
> DZ1*(R1*0.5D0*(PAR1+S1)-RSMRFS*F1/R1)/A1)*0.5D0*PI/(RF*SL)	SOL01
RETURN	SOL01
END	SOL01